ILLUMINATION DESIGN DATA

- ▲LIGHTING STANDARDS AND SYSTEMS
- ▲GENERAL INTERIOR LIGHTING DESIGN
- ▲SUPPLEMENTARY LIGHTING METHODS
- ▲FLOODLIGHTING—SPORTS LIGHTING
- ▲LUMINOUS ARCHITECTURAL ELEMENTS

GENERAL ELECTRIC
COMPANY
NELA PARK ENGINEERING DEPT.
CLEVELAND, OHIO

ILLUMINATION DESIGN

Illuminating Engineering is continuously embracing new fields of application. At no time has the practice of the art and science of illumination been so interesting and so expansive as in the present era. At no time has Illuminating Engineering served so broad a viewpoint—in eyesight conservation and human welfare, in decoration and esthetics, in safety and convenience—as it does today.

Lighting practice has evolved from elementary homespun methods to orderly, well-planned systems which in general are relatively simple as far as design is concerned. These simpler concepts of lighting design are now being broadened by new light sources, new reflecting surfaces, new methods and new technique, all of which must be given consideration. The general acceptance of architectural lighting involves individual design, well conceived as to adequacy of lighting result, satisfactory in decorative purpose, and achieved with engineering skill and efficiency.

This bulletin is not intended as a treatise on illumination principles and practice, but only as an outline of procedure in lighting design, with a compilation of essential design data and tables of value to engineers, architects and others responsible for lighting design and installation.

Ward Harrison
C. E. Weitz

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ILLUMINATION DESIGN DATA

GENERAL ELECTRIC COMPANY
NELA PARK ENGINEERING DEPARTMENT
CLEVELAND, OHIO

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LIGHTING DESIGN AND SPECIFICATION

● Every designer should approach lighting problems not alone from the standpoint of present practice, but should try to extrapolate or project his viewpoint along the trend curve of future progress. The almost universal need for improvement of existing lighting even in our newer buildings is the best evidence to recommend a new and more scientific approach to lighting design problems. That lighting does have inherent benefits and does serve a fuller purpose beyond its best usage today is evidenced not only by lighting research but also by the favorable reaction to each new installation that pioneers new standards. Lighting design and specification deals not only with new construction projects, but even to a greater extent, is concerned with improvement of existing systems to make them more effective.

● The first and most fundamental question on lighting design is the one inquiring as to the real objective to be accomplished in lighting. In seeking an answer to this question, it is necessary to depart from traditional engineering boundaries and enter a totally different realm—that of human reactions—of likes and dislikes, of health, heritage and habit; only here can we find the full significance and purpose of lighting. The second question that arises is concerned with the engineering method and technique to be employed to fulfill the basic purposes.

● Lighting specification as regards both quantity of light and quality of lighting must logically be based on first how light affects visual processes, following through to the end product of contribution to human welfare. Definite and measurable scientific facts have come out of an orderly program of research on seeing which have placed new responsibilities on the designer of lighting. These new responsibilities deal directly with the conservation of eyesight, health, and safety of those who use the lighting.

ILLUMINATION DESIGN DATA

The problem of lighting today and of the future will be approached and proceed more from the point of view of "ease of seeing." The most recent and perhaps the most noteworthy researches in seeing are those which have revealed that seeing is a task, accomplished not by eyes alone but by the whole body, in quite the same way that lifting a weight is not a task for the arms or back alone, but also has telling effect upon the heart, lungs, and the whole nerve fibre. This vital aspect is revealed, for example, by actual measurements of nervous muscular tension due to the work of seeing under different lighting conditions. It explains why people who use their eyes under inadequate or glaring lighting conditions are subject to eyestrain effects which translate themselves into nervousness, indigestion, fatigue and other disorders seemingly remote from the cause.

"Ease of seeing" is indicated by measurements of visibility. Scientific explorations of visibility are not new; in fact, most of the earlier researches on seeing were concerned with visibility measurements. The visibility of an object depends on a number of factors, all complexly interrelated. The job of early research was to unravel, align and prove these complex relations. The principal

PART 1

ILLUMINATION STANDARDS AND TYPES OF LIGHTING SYSTEMS

factors related to visibility of an object are:

1. Its size, or the size of certain critical details;
2. Its distance from the eye;
3. Its contrast with the background;
4. Its brightness, which depends upon its reflection factor and illumination;
5. The time available for seeing;
6. The ability of the eyes, which depends upon their freedom from defects or upon the correction of glasses;
7. The ability of the person, which depends upon many factors, such as intelligence, experience, reaction time, concentration, distraction and fatigue;
8. Other visual and lighting factors, such as glare, adaptation, and color, brightness and pattern of surroundings.

VISIBILITY METER INTEGRATES COMPLEX FACTORS

It is a matter of common experience that certain seeing tasks are more difficult than others. Everyone has an appreciation that small objects are harder to see than large ones, and that poor contrast and dark backgrounds make seeing more difficult. How much more difficult, it has heretofore been impossible to state except in the most general terms. The Visibility Meter, however, unites all the factors concerned in visibility and gives in a single reading an integrated result of the relative visibility of objects under different conditions. This also is a fair measure of the "ease of seeing."

▲ The Luckiesh-Moss Visibility Meter

With ten footcandles on this bench, the observer is examining typical seeing tasks of office and shop with a Visibility Meter. ▼

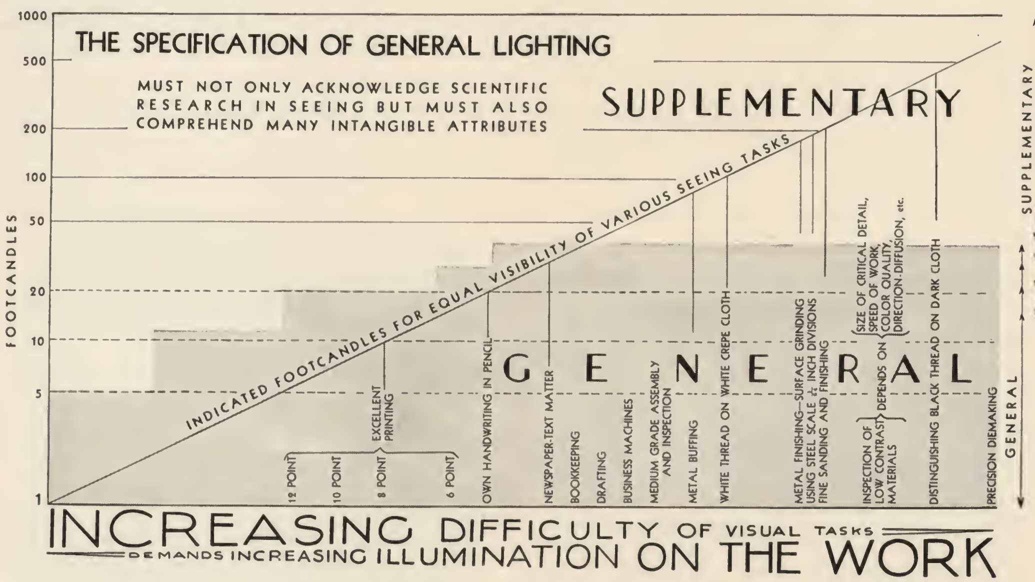
The Visibility Meter is a direct reading instrument provided with two scales. By looking through this instrument at any object or seeing task, the visibility or ease of seeing this object or task can be compared directly to the visibility of any other task under actual seeing conditions as they prevail. This is shown by the "relative visibility" scale on the meter. The second scale indicates the footcandles necessary to bring various objects or seeing tasks of a wide range of severity up to the same degree of visibility or ease of seeing as reading this paragraph, which is set in 8 point Bodoni Book Type, under 10 footcandles of illumination. The Visibility Meter may show that 10 footcandles of suitable quality lighting is as effective as 100 footcandles where the quality of lighting has been neglected.

VISIBILITY READINGS BASIS FOR FOOTCANDLE STANDARDS FOR VARIOUS SEEING TASKS

Tables of recommended footcandle values have for many years served as an acceptable guide to current practice, and such tables will continue to have this practical advantage. However, as we begin to appreciate the significance and implications of lighting in the broader sense, the need for fitting lighting more definitely to each specific seeing task becomes apparent. This means that while certain arbitrary standards of general illumination can be set up, they embrace general conditions only. Beyond this, seeing tasks of all degrees of severity

are encountered which dictate specialized lighting for many specific areas or kinds of work. The Visibility Meter allows quantitative appraisal of each seeing task and thus permits determining accurately and with assurance the amount of light to equalize seeing tasks on whatever basis of "ease" that is logical. While it is possible to perform the standard task under a fraction of one footcandle, research has shown that from the standpoint of fatigue, nervous muscular tension, and other effects, definite measurable advantages accrue up to and beyond 100 footcandles; more severe tasks would of course require correspondingly higher levels. The calibration base for the instrument, that is, the reading of 8 pt. Bodoni Book type under 10 footcandles, therefore, seems conservative and practical, though much below the ideal.

On the other hand it is not expected that all seeing regardless of its difficulty can or should be made equally easy. Where highly critical seeing of minute detail is required constantly or for prolonged periods, the highest practical standard of lighting should be provided. Where such critical seeing is imposed only intermittently, the eye may be expected to extend itself for short periods without ill effects. Such conditions are common particularly in factory and office work but they apply also in stores in the critical examination of color and texture of materials. The lighting engineer realizes that cost always must be acutely balanced against value and that the practical prescription of illumination must weigh all of the elements of value and benefit against cost. Although it is recognized that in the past the question of expense



This sketch indicates how a great variety of seeing tasks encountered in the work-world might be charted, as far as amount of light and relative visibility are concerned. If this chart were long enough to write in hundreds of conditions on which visibility measurements had been made, an encyclopedia of recommended footcandle values might thus be established for all manner of seeing tasks based on standards of equal visibility or "ease of seeing."

The amount of general lighting to be specified, whether as a part of a general plus supplementary system or purely general lighting, depends not only upon the knowledge of scientific aspects of seeing and consideration of immediate cost but also upon many other factors such as freedom in the rearrangement of industrial machines or office furniture and the atmosphere desired in the room.

The shaded area represents the region of practical levels of general illumination at the present time; where higher levels are indicated by Visibility Meter tests, they can be readily supplied by supplementary local lighting over a restricted area.

has been given altogether too much weight, still it must be expected that cost will always tend to force a compromise with ideal standards.

The foregoing brief discussion of the Visibility Meter serves merely to introduce and to establish the scientific basis for the specification of lighting, as far as visibility is concerned. The tables of recommended footcandle standards published in this bulletin for different tasks are, in general, much less than would be indicated by the Visibility Meter. While standards considerably higher than those listed in Table 1 are in service in practically every class of lighting installation, the vast majority of existing lighting falls far short of attaining these conservative standards.

The footcandle values given are recognized as conservative levels of illumination when appraised on the basis of quick, accurate, easy seeing, and represent therefore, order of magnitude rather than exact levels. These values are meant to apply to the average result in service, so in designing a lighting system a reasonable allowance should be made for depreciation.

MEASUREMENTS WITH THE G-E LIGHT METER

The General Electric Light Meter, compact and inexpensive, represents a forward step in the progress of lighting science. It is a simple, direct-reading instrument which enables business establishments to have at little cost a practical light measuring device with which to keep close check on their lighting at all times in order to assure its being adequate for safe seeing and good working conditions.

The light-sensitive cell is located on the top surface at right angles to the scale face. This arrangement not only makes it convenient for taking footcandle readings avoiding observer's shadow but permits the meter to be used for the measurement of reflection factors of ceiling, walls, or other light-reflecting surfaces. Similarly it may be used to measure transmission factors of all types of glass or other translucent materials.

The many-sided services of this small meter recommend it for school classroom use—not alone for constant check of classroom lighting conditions, but for use in physics and science classes as a basis for laboratory experiments and measurements in the study of light.

The use of the Light Meter becomes increasingly important in the measurement of reflection and transmission factors and brightness values because of the trend toward individualized design and the use of new materials. While reference tables are available which give average or a range of values, the lighting engineer will be repeatedly confronted with the need for making quick, practical measurements of actual brightness values and of the performance of specific materials at hand.

Suggestions for making measurements are given on the opposite page.

This G-E Light Meter closely resembles a small thin desk clock. It is $2\frac{1}{4}$ inches square and $1\frac{1}{8}$ inches thick and can be carried in the vest pocket. The normal scale range of the meter is from 0 to 75 footcandles but each meter is provided with a multiplying shield so that illumination values up to 750 footcandles can be read.

Brightness in Foot-Lamberts

The unit most commonly used in general lighting practice to express brightness is the foot-lambert. To measure the foot-lambert brightness of a diffusely reflecting surface, place the cell of the Light Meter against the surface to be measured, drawing the meter slowly back two to four inches from the surface until a constant reading is obtained. Take reading at this point and multiply by 1.25 to give the correct value of brightness in foot-lamberts. For measuring translucent surfaces the meter is placed with the cell in contact with the luminous surface. A reading of 75, for example, indicates 94 foot-lamberts. By using the 10 to 1 multiplying shield furnished with the meter, brightness measurements up to 940 foot-lamberts can be made.

Reflection Factor

To measure the reflection factor of a wall or other surface, place the cell of the Light Meter against the wall or other surface to be measured, drawing it back slowly about two to four inches until a constant reading is obtained. Note this reading. Then turn the Light Meter around and place it against the surface with the cell facing away from the surface and take a second reading. Dividing the first reading by the second will give the approximate reflection factor of a diffusely reflecting surface.

Transmission Factor

To find the approximate transmission factors of all types of glasses or other translucent materials, simply divide the reading that is taken when the sample of glass is placed over the cell, as shown, by the reading taken when the sample is removed. The quotient is the transmission factor.

It is quite important to check transmission of specific translucent materials, since values such as given on page 59 must either carry specific data as to thickness and coloring of tested samples, or else present such a wide range as to be of little value as an aid to design.

TABLE No. 1

RECOMMENDED STANDARDS OF ILLUMINATION

STORES

For store interiors, high levels of illumination are desirable to facilitate seeing, yet other aspects, such as making the interior attractive to create an atmosphere which will stimulate sales, are particularly valuable to the store owner. In lighting, the storekeeper has a versatile and flexible medium for advertising and decoration. Hence a factor in the well-lighted store is the exercising of ingenuity and artistic ability in connection with general lighting along with special lighting for prominent merchandise displays. Briefly, light attracts prospective customers, which makes its use a factor of importance in meeting competition.

(THESE FOOTCANDLE VALUES REPRESENT ORDER OF MAGNITUDE RATHER THAN EXACT LEVELS OF ILLUMINATION.)

	General Interior Lighting	Show-case (See p. 37)	Special Displays Inside Store (See pages 38 and 39)			Show Window (See p. 37)	Lighting to Reduce Daylight Window Reflections
			Light Colored	Medium Colored	Dark Colored		
	FOOTCANDLES						
Large Cities							
Brightly Lighted District	20	50–100	30–50	50–100	100 or More	200	200–1000
Secondary Business Locations	20	50–100	30–50	50–100	100 or More	100	200–1000
Neighborhood Stores	15	50–100	30–50	50–100	100 or More	50	200–1000
Medium Cities							
Brightly Lighted Districts	20	50–100	30–50	50–100	100 or More	100	200–1000
Neighborhood Stores	15	50–100	30–50	50–100	100 or More	50	200–1000
Small Cities and Towns	15	50–100	30–50	50–100	100 or More	50	200–1000

★

Showing how daylight illumination falls off away from a window. In this classroom on a clear day pupils near the window receive about 90 footcandles, the illumination falling off rapidly to only 5 footcandles on the inner row of desks. On cloudy and dark days the values are much less.

TABLE No. 1 (Continued)

COMMERCIAL AND PUBLIC INTERIORS

In offices, drafting rooms, school classrooms and other interiors in which the visual tasks are difficult and prolonged, it is of prime importance to consider lighting not for *barely* seeing but for *easy* seeing. Not only is high-level general illumination required, but supplementary lighting is often necessary on desks, business machines, and blackboards. Such local lighting must be chosen with careful attention to shading, diffusion, shadows, and reflected glare.

(THESE FOOTCANDLE VALUES REPRESENT ORDER OF MAGNITUDE RATHER THAN EXACT LEVELS OF ILLUMINATION.)

The letters A, B, and C refer to footcandle ranges as explained on Page 35. These levels are usually, though not always, best obtained by supplementary or specialized lighting which may be accomplished by one or more of the methods referred to and discussed in Part III.

	Footcandles
Armories—Drill Sheds and Exhibition Halls	10
Art Galleries	
General	5
On Paintings	B–Page 36 (a)
Auditoriums	5
Automobile Showrooms	20
Banks	
Lobby	10
Cages	B–Page 36 (e)
Offices	20
Barber Shops and Beauty Parlors	20
Churches	
Auditoriums	5
Sunday School Rooms	10
Pulpit or Rostrum	15
Club and Lodge Rooms	
Lounge and Reading Rooms	20
Auditoriums	5
Courtrooms	10
Dance Halls	5
Drafting Rooms	30
Fire Engine Houses	
When alarm is turned in	10
At other times	2
Garages—Automobile	
Storage—Dead	2
Live	10
Repair and Washing Departments	C–Page 40 (a, b, c)
Hangars—Aeroplane	10
Repair Department	C–Page 40 (b)
Hospitals	
Corridors	2
Laboratories	20
Lobby and Reception Room	5
Operating Room	20
Operating Table	A–Page 36 (c)
Private Rooms and Wards (with local illumination)	20
Hotels	
Lobby	10
Dining Room	5
Kitchen	10
Guestrooms	10
Corridors	2
Writing Rooms	20
Libraries	
Reading Room	20
Stack Room	10
Moving Picture Theatres	
During Intermission	5
During Pictures	0.1
Museums	
General	10
Special Displays	B–Page 36 (b)
Night Clubs and Bars	5
Office Buildings	
Bookkeeping, Typing and Accounting	30
Business Machines, Power Driven (Transcribing and Tabulating)—Calculators, Key Punch, Bookkeeping	B–Page 36 (f)
Conference Room—	
General Meetings	10
Office Activities—See Desk Work	
Corridors and Stairways	5
Desk Work—	
Intermittent Reading and Writing	20
Prolonged Close Work, Computing, Studying, Designing, etc.	30–50
Reading Blueprints and Plans	30
Drafting—	
Prolonged Close Work—Art Drafting and Designing in Detail	30–50
Rough Drawing and Sketching	30
Filing and Index References	20
Mail Sorting	20
Reception Rooms	10
Stenographic Work—	
Prolonged Reading Shorthand Notes	30–50
Vault	10
Post Offices	
Lobby	10
Sorting, Mailing, etc.	20
Storage	10
Offices—Private and General	20
File Room and Vault	10
Corridors and Stairways	2
Professional Offices	
Waiting Rooms	10
Consultation Rooms	20
Operating Offices	20
Dental Chairs	C–Page 36 (d)
Restaurants, Lunch Rooms and Cafeterias	
Dining Area	10
Food Displays	C–Page 38-39
Schools	
Auditoriums	10
Classrooms, Library and Offices	20
Corridors and Stairways	5
Drawing Room	30–50
Gymnasium (Basketball)	20
Laboratories	15
Manual Training	20
Sewing Room	B–Page 40 (f)
Sight-Saving Classes	30–50
Study Rooms—Desks and Blackboards	20
Service Space	
Corridors	5
Elevators—Freight and Passenger	10
Halls and Stairways	5
Lobby	10
Storage	5
Toilets and Wash Rooms	5
Telephone Exchanges	
Operating Rooms	10
Terminal Rooms	15
Cable Vaults	5
Theatres	
Auditoriums	5
Foyer	10
Lobby	15
Transportation	
Cars—	
Baggage, Day Coach, Dining, Pullman	15
Mail—	
Bag Racks and Letter Cases	20
Storage	5
Street Railway, Trolly Bus and Subway	15
Motor Bus	10
Depots—	
Waiting Rooms	10
Ticket Offices—	
General	10
Ticket Rack and Counters	B–Page 36 (e)
Rest Rooms, Smoking Rooms	10
Baggage Checking Office	15
Storage	5
Concourse	5
Platforms	2

TABLE No. 1 (Continued)

INDUSTRIAL INTERIORS

Factory workers are charged with a responsibility for maintaining certain standards of speed, accuracy, and perfection. Inability to see quickly and accurately is the cause of slower production, errors, accidents. Under ordinary lighting many circumstances such as high speed production, distracting surroundings, fatigue, may actually reduce seeing conditions close to or even below threshold where neither certainty nor accuracy of seeing is possible. This tendency is definitely counteracted by higher standards of lighting, and recommended levels of illumination must provide an adequate safety factor in order to maintain visibility well above threshold values for critical tasks, and to provide a sufficient margin so that ordinary routine tasks may be accomplished with greater ease and less ocular fatigue.

Critical inspection demands a high standard of lighting, both in quantity of light and quality of lighting. It is uneconomical from the standpoint of loss of time and material if processes must proceed to the point of final inspection before flaws and defects are apprehended, particularly if, by the same adequate lighting on the work, the worker himself might have avoided these faults.

(THESE FOOTCANDLE VALUES REPRESENT ORDER OF MAGNITUDE RATHER THAN EXACT LEVELS OF ILLUMINATION.)

The letters A, B, and C refer to footcandle ranges as explained on Page 35. These levels are usually, though not always, best obtained by supplementary or specialized lighting which may be accomplished by one or more of the methods referred to and discussed in Part III.

	Footcandles
Aisles, Stairways, Passageways	2
Assembly	
Rough	10
Medium	20
Fine	B–Page 41 (h)
Extra Fine	A–Page 41 (h)
Automobile Manufacturing	
Assembly Line	B–Page 40 (d)
Frame Assembly	15
Body Manufacturing—	
Assembly	20
Finishing and Inspecting	A–Page 40 (d)
Bakeries	20
Bookbinding	
Folding, Assembling, Pasting, etc	10
Cutting, Punching and Stitching	20
Embossing	20
Breweries	
Brew House	5
Boiling, Keg Washing and Filling	10
Bottling	15
Candy Making	20
Canning and Preserving	20
Chemical Works	
Hand Furnaces, Boiling Tanks, Stationary Driers, Stationary and Gravity Crystallizers	5
Mechanical Furnaces, Generators and Stills, Mechanical Driers, Evaporators, Filtration, Mechanical Crystallizers, Bleaching	10
Tanks for Cooking, Extractors, Percolators, Nitrators, Electrolytic Cells	15
Clay Products and Cements	
Grinding, Filter Presses, Kiln Rooms	5
Molding, Pressing, Cleaning and Trimming	10
Enameling	15
Color and Glazing	20
Cloth Products	
Cutting, Inspecting, Sewing—	
Light Goods	20
Dark Goods	A–Page 40 (e, f)
Pressing, Cloth Treating (Oilcloth, etc.)—	
Light Goods	10
Dark Goods	20
Coal Breaking and Washing, Screening	5

	Footcandles
Construction—Indoor General	10
Dairy Products	20
Elevators—Freight and Passenger	10
Engraving	A–Page 41 (j)
Forge Shops and Welding	10
Foundries	
Charging Floor, Tumbling, Cleaning, Pouring and Shaking Out	5
Rough Molding and Core Making	10
Fine Molding and Core Making	20
Garages—Automobiles	
Storage—Live	10
Dead	2
Repair Department and Washing	C–Page 40 (a, b, c)
Glass Works	
Mix and Furnace Rooms, Pressing and Lehr, Glass Blowing Machines	10
Grinding, Cutting Glass to Size, Silvering	20
Fine Grinding, Polishing, Beveling, Etching and Decorating	C–Page 41 (l, m, n)
Inspection	B–Page 41 (k, m, n)
Glove Manufacturing	
Light Goods—	
Cutting, Pressing, Knitting, Sorting	10
Stitching, Trimming and Inspecting	20
Dark Goods—	
Cutting, Pressing, Knitting, Sorting	20
Stitching, Trimming and Inspecting	A–Page 40 (e, f)
Hangers—Aeroplane	
Storage—Live	10
Repair Departments	C–Page 40 (b)
Hat Manufacturing	
Dyeing, Stiffening, Braiding, Cleaning and Refining—	
Light	10
Dark	20
Forming, Sizing, Pouncing, Flanging, Finishing and Ironing—	
Light	15
Dark	30
Sewing—	
Light	20
Dark	A–Page 40 (f)
Ice Making—Engine and Compressor Room	10

INDUSTRIAL INTERIORS (*Continued*)

	Footcandles
Inspection	
Rough	10
Medium	20
Fine	B–Page 41 (h to n)
Extra Fine	A–Page 40 (h to n)
Jewelry and Watch Manufacturing	A–Page 40 (j)
Laundries and Dry Cleaning	20
Leather Manufacturing	
Vats	5
Cleaning, Tanning and Stretching	10
Cutting, Fleshing and Stuffing	15
Finishing and Scarfing	20
Leather Working	
Pressing, Winding and Glazing—	
Light	10
Dark	20
Grading, Matching, Cutting, Scarfing, Sewing—	
Light	20
Dark	A–Page 40 (f)
Locker Rooms	5
Machine Shops	
Rough Bench and Machine Work	10
Medium Bench and Machine Work, Ordinary Automatic Machines, Rough Grinding, Medium Buffing and Polishing	20
Fine Bench and Machine Work, Fine Automatic Machines, Medium Grinding, Fine Buffing and Polishing	B–Page 41 (k)
Extra Fine Bench and Machine Work, Grinding—	
Fine Work	A–Page 41 (k)
Meat Packing	
Slaughtering	10
Cleaning, Cutting, Cooking, Grinding, Canning, Packing	20
Milling—Grain Foods	
Cleaning, Grinding, and Rolling	10
Baking or Roasting	20
Flour Grading	30
Offices (See Office Buildings page 9)	
Private and General—	
No Close Work	10
Close Work	20
Drafting Rooms	30
Packing and Boxing	10
Paint Manufacturing	10
Paint Shops	
Dipping, Spraying, Firing, Rubbing, Ordinary Hand Painting and Finishing	20
Fine Hand Painting and Finishing	B–Page 40 (g)
Extra Fine Hand Painting and Finishing (Automobile Bodies, Piano Cases, etc.)	A–Page 40 (g)
Paper Box Manufacturing	
Light	10
Dark	20
Storage of Stock	5
Paper Manufacturing	
Beaters, Grinding, Calendering	10
Finishing, Cutting, Trimming	20
Plating	10
Polishing and Burnishing	15
Power Plants, Engine Rooms, Boilers	
Boilers, Coal and Ash Handling, Storage Battery Rooms	5
Auxiliary Equipment, Oil Switches and Transformers	10
Switchboards, Engines, Generators, Blowers, Compressors	15
Printing Industries	
Matrixing and Casting	10
Miscellaneous Machines	15
Presses and Electrotyping	20
Lithographing	B–Page 41 (j)
Linotype, Monotype, Typesetting, Imposing Stone, Engraving	B–Page 40, 41 (f, j)
Proofreading	B–Page 40, 41 (f, j)
Receiving and Shipping	10
Rubber Manufacturing and Products	
Calenders, Compounding Mills, Fabric Preparation, Stock Cutting, Tubing Machines, Solid Tire Operations, Mechanical Goods Building, Vulcanizing	10
Bead Building, Pneumatic Tire Building and Finishing, Inner Tube Operation, Mechanical Goods Trimming, Treading	20
Sheet Metal Works	
Miscellaneous Machines, Ordinary Bench Work	15
Punches, Presses, Shears, Stamps, Welders, Spinning, Medium Bench Work	20
Tin Plate Inspection	C–Page 41 (j)
Shoe Manufacturing	
Hand Turning, Miscellaneous Bench and Machine Work	10
Inspecting and Sorting Raw Material, Cutting and Stitching—	
Light	20
Dark	A–Page 40 (f)
Lasting and Welting	20
Soap Manufacturing	
Kettle Houses, Cutting, Soap Chip and Powder	10
Stamping, Wrapping and Packing, Filling and Packing Soap Powder	20
Steel and Iron Mills, Bar, Sheet and Wire Products	
Soaking Pits and Reheating Furnaces	5
Charging and Casting Floors	10
Muck and Heavy Rolling, Shearing, rough by gauge, Pickling and Cleaning	10
Plate Inspection, Chipping	C–Page 41 (j)
Automatic Machines, Light and Cold Rolling, Wire Drawing, Shearing, fine by line	15
Stone Crushing and Screening	
Belt Conveyor Tubes, Main Line Shafting Spaces, Chute Rooms, Inside of Bins	5
Primary Breaker Room, Auxiliary Breakers under Bins	5
Screens	10
Storage Battery Manufacturing	
Molding of Grids	10
Store and Stock Rooms	
Rough Bulky Material	2
Medium or Fine Material requiring care	10
Structural Steel Fabrication	10
Sugar Grading	30
Testing	
Rough	10
Fine	20
Extra Fine Instruments, Scales, etc.	A–Page 41 (h)
Textile Mills	
Cotton—	
Opening and Lapping, Carding, Drawing, Roving, Dyeing	10
Spooling, Spinning, Drawing, Warping, Weaving, Quilling, Inspecting, Knitting, Slashing (over beam end)	20
Silk—	
Winding, Throwing, Dyeing	15
Quilling, Warping, Weaving, Finishing—	
Light Goods	15
Dark Goods	30
Woolen—	
Carding, Picking, Washing, Combing	10
Twisting, Dyeing	10
Drawing-in, Warping—	
Light Goods	15
Dark Goods	30
Weaving—	
Light Goods	15
Dark Goods	30
Knitting Machines	20
Tobacco Products	
Drying, Stripping, General	10
Grading and Sorting	A–Page 34 (A, B)
Toilets and Wash Rooms	5
Upholstering—Automobile, Coach, Furniture	20
Warehouse	5
Woodworking	
Rough Sawing and Bench Work	10
Sizing, Planing, Rough Sanding, Medium Machine and Bench Work, Gluing, Veneering, Cooperage	20
Fine Bench and Machine Work, Fine Sanding and Finishing	30

LIGHTING SYSTEMS AND METHODS

The lighting "fixture" is undergoing significant changes with the development of new diffusing and reflecting materials, with design trends affecting appearance and styling, and with the growing acceptance of "built-in" architectural systems. These changes are influenced by (1) the generally higher levels of illumination desired, (2) refinement in quality and character of illumination with the result that users are becoming less and less tolerant of lighting that is uncomfortable and irritating and (3) flexibility and convenience of switching and control.

The departures from older forms offer a much wider range of choice of methods of lighting but affect basic design procedure and calculation very little.

Lighting systems may be grouped into four types: (1) Direct; (2) Semi-Direct; (3) Semi-Indirect, and (4) Indirect. The general characteristics of any system prevail even though details of equipment design and installation may vary considerably.

Direct Lighting

Defined as any system in which substantially all of the light on the working surfaces is essentially downward and comes directly from the lighting units. Direct lighting methods may range from concentrating and spotlight types of equipment through the many types of bowl and dome type reflectors to extended light source areas such as large glass panels and skylights. To provide high levels of illumination without glare with open type reflectors, though most efficient, is difficult unless considerable care is taken in locating and shielding such sources. This has led to many modern systems employing louvered downlights with concentrating reflector or lens control to confine the light narrowly to the seeing plane, with a minimum of light in the direction of the eyes; proper location of equipment is very important to obtain good distribution, to avoid harsh shadows, and to minimize glaring reflections from shiny or polished surfaces. Large area sources of low brightness and good diffusion approach the characteristics of indirect lighting, in that harsh shadows and both direct and reflected glare are minimized.

Semi-Direct

This classification refers to systems where the predominant light on horizontal working surfaces comes from the lighting units but where there is also a considerable contribution by reflection from the ceiling as would be the case with enclosing opal or prismatic glass globes. Such units direct the light out at all angles and are likely to be too bright for offices, schools and other similar locations unless oversize globes are used. Installation of such units can oftentimes be greatly improved by equipping the globes with parchment shades to reduce the brightness toward the eye and at the same time redirect the light more efficiently to the work surfaces.

Semi-Indirect

Defined as any system in which some light—usually from 5 to 25 per cent—is transmitted directly downward but over half of the emitted light is upward depending largely upon reflection from the ceiling. Luminaires of good design should be of such density and diffusion that the surface brightness of the bowl will not exceed 500 foot-lamberts. Semi-indirect illumination has the same general characteristics and field of application as indirect lighting but is sometimes preferred because of the luminous appearance yet low brightness of the luminaires. Opaque units which employ baffles or shielded openings to redirect a small part of the light to their undersurfaces for decorative effect only would be classed as indirect units.

Indirect

Characterized by the soft, subdued atmosphere created by low brightness and by the absence of sharp shadows, since practically all of the light is diffusely reflected from large ceiling areas. Permits a wide range of installation technique from simple suspended or portable luminaires to built-in concealed sources in the form of coves, ceiling coffers, column urns, and wall boxes. Appearance demands a fair uniformity of ceiling brightness. In long, low-ceilinged rooms, large expanses of ceiling area are brought within the normal line of vision and may become uncomfortable after a few hours in installations intended to produce 25 footcandles or more. This condition is less serious where ceiling areas are divided by projecting crossbeams, or where occasional ceiling valances are employed to break up an otherwise flat, expansive ceiling area.

Architectural Fitness—Atmosphere

No lighting system is completely satisfactory if it meets only the purely utilitarian needs, though these be the prime consideration. Except perhaps in factories or other workshops where the installation of utility lighting is governed largely by considerations of efficiency, ruggedness, and simplicity, the majority of lighting applications in commercial and public buildings call for some decorative treatment. *Unless seeing requirements are fully met*, the major purpose of a lighting system is defeated, and no amount of decorative art can make up for this deficiency. The final object of illuminating engineering is to better the conditions under which people work and live, to make lighting yield its full contribution to human welfare, and to evoke emotions that are pleasant and satisfying. The recognition of this truth has done much in recent years to coordinate lighting with architectural planning, as witnessed by a distinct trend away from the simple "tacked-on" system of suspended luminaires and toward completely coordinated architectural lighting systems.

No other medium is more versatile or expressive than light. As such, lighting should always be coordinated with the aims of the decorator. The lighting engineer must sense the character or atmosphere desired and, by intelligent regard for lighting tone and accent, express the feeling of the interior in such a way that the whole is accentuated by a harmonious and tasteful scheme of lighting. Thus he has a scale range from the quiet hushed atmosphere of a library reading room to the colorful scintillation of a night club.

Comfort Factors—Avoidance of Direct and Reflected Glare

It is sometimes stated that the "efficiency" of a lighting system is never adequately expressed in the narrow sense of "so many footcandles per watt per square foot," but should be gauged rather by the all-around satisfactory character of the system. Every refinement is generally a compromise with efficiency in the strict sense. Just as a large portion of the crude stone must be cut away to produce a finished gem, so the efficiency of a lighting system must often be reduced to gain comfortably diffused light, a pleasing appearance or a purely decorative effect. This is an acceptable viewpoint but not an excuse for inefficiency and waste that might be avoided by intelligent engineering design.

Any installation which merely achieves specified standards of footcandles, at the sacrifice of comfort, is neither economical nor acceptable. In this respect the presence of glare or reflected glare is the principal offender. Direct glare is the most frequent and serious cause of bad lighting. It results, among other things, from unshaded or inadequately shaded light sources located within the field of vision, or from too great a contrast between the bright light source and a dark background, or adjacent surfaces. Glare can be avoided by the proper choice

and location of reflecting and diffusing equipment.

Reflected glare comes from polished objects, such as encountered in machining metal parts, inspection of flat tinplate and other shiny surfaces; from glass-top or varnished desks or from glossy paper and paint. It is generally impossible to change the character of work or nature of the seeing task in order to avoid these potential reflections but the lighting engineer, alert to all such conditions, can minimize these reflections by (1) properly shielding the light source, (2) specifying a source of such dimensions that it is of low brightness or (3) by locating the light source in such a manner that most of the reflection is away from the eyes.

Surroundings and Contrasts

Every work interior should have the illumination throughout the room so proportioned as to reduce severe brightness contrasts. In this respect proper painting of ceiling, walls, and columns, as well as the color and finish of machinery, equipment and furnishings is an important ally in producing comfortable seeing conditions. The basis for this is not only the obvious effect of transforming a dingy, gloomy atmosphere into one of cheerfulness and alertness, but concerns a well-founded principle of eye comfort. Avoidance of frequent pupillary adaptation to changes in brightness relieves the eye muscles and lessens eye fatigue which may cause headaches or other manifestations of eye abuse. These facts necessitate the specification of a basic general lighting system supplemented by additional localized lighting where seeing tasks are severe, or on display areas where it is desirable to compel attention and center interest.

Shadows are merely differences in brightness of surfaces that can be regulated by the choice and location of lighting equipment. While some shadow is essential in discerning objects in their three dimensions, rarely, if ever, should shadows be harsh and pronounced. Where shadows are desirable, they should be soft and luminous, not so sharp and dense as to confuse the object with its shadow. Shadows are most severe where light is contributed essentially from one unit, such as a bare lamp in an open-bowl reflector; they are least where the light source is diffused over a wide area, as obtained with indirect lighting systems.

Color Quality and Color Effects

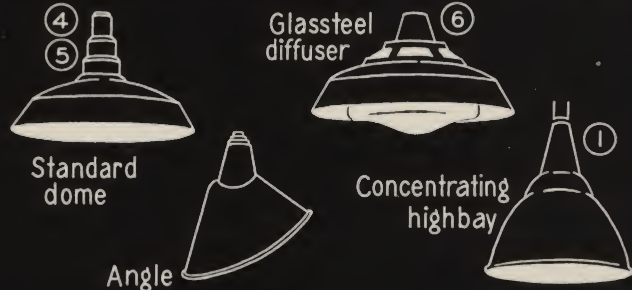
The subject of color quality concerns not only the matter of color discrimination, but it also has to do with a certain feeling of comfort and satisfaction. With the wide range of illuminants now available both in MAZDA incandescent lamps with their many color accessories, and in gaseous conductor sources, the illuminating engineer, if prepared to sacrifice quantity, can produce practically any spectral quality of light desired. From the standpoint of color discrimination, interest in the subject of color quality centers largely around the production of white light, or in matching seeing habits formed under certain conditions of daylight. Equipments for this purpose are discussed in more detail on page 34.

In addition to the question of color discrimination, there are other psychological considerations involving color quality of light, particularly in offices, stores and schools, where a color which will blend with natural daylight is desirable.

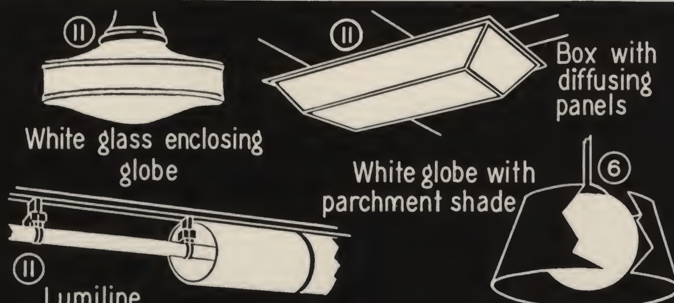
Various types of mercury, sodium and other gaseous conductor lamps are widely used for illumination purposes where color quality of illumination is not important as there may be decided distortion in the natural appearance of some colored objects under such illuminants.

The question of "color effects" is largely confined to decorative and spectacular lighting and general satisfactory installations require considerable artistic and decorative talent. The psychology of color is an interesting study in itself.

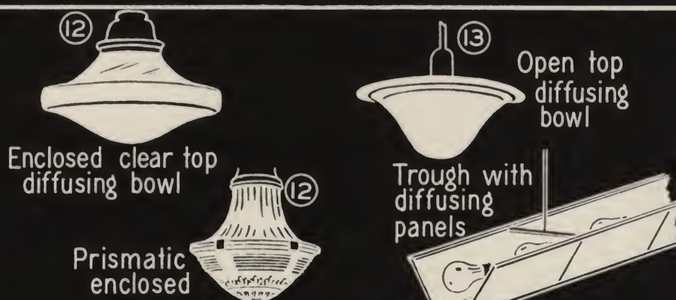
SUSPENDED AND PORTABLE LIGHTING EQUIPMENT



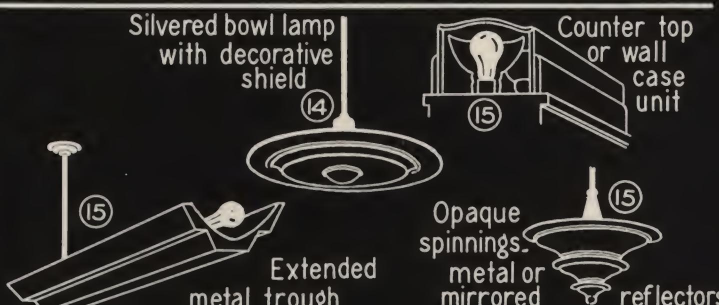
TYPICAL DIRECT LIGHTING LUMINAIRES



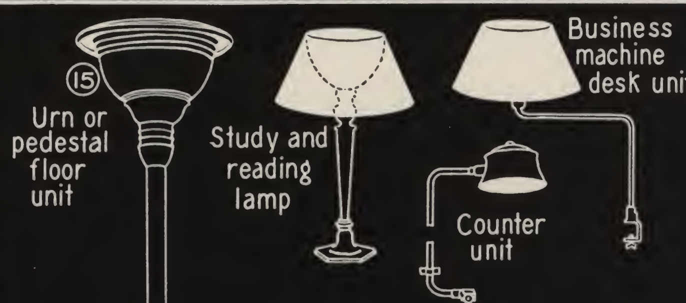
TYPICAL SEMI-DIRECT LIGHTING LUMINAIRES



TYPICAL SEMI-INDIRECT LIGHTING LUMINAIRES



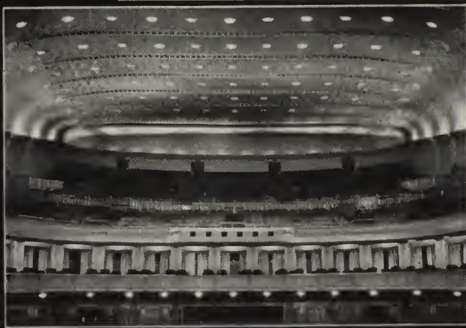
TYPICAL INDIRECT LIGHTING LUMINAIRES

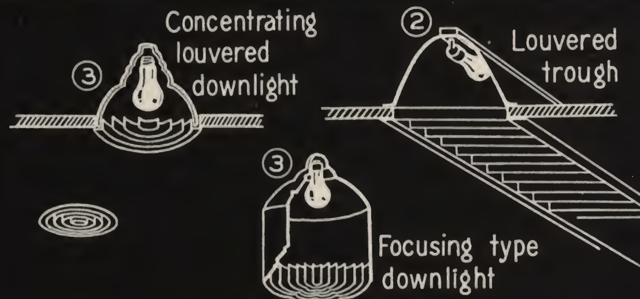


TYPICAL PORTABLE LUMINAIRES

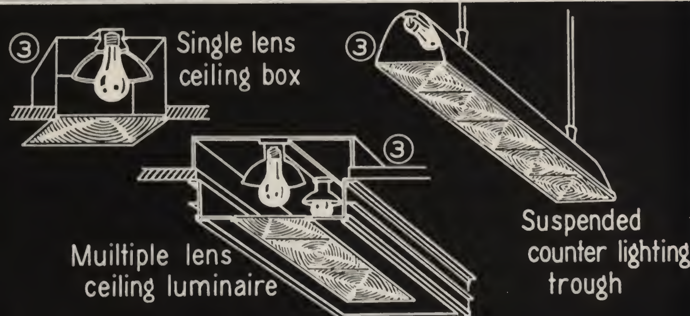
Figures in circles refer to corresponding classifications in the Coefficient of Utilization Tables

BUILT-IN DIRECT LIGHTING METHODS

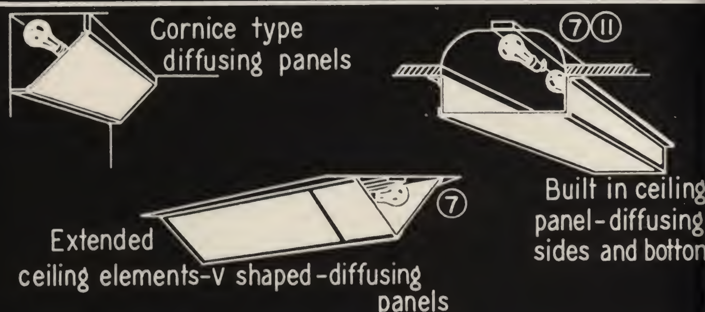




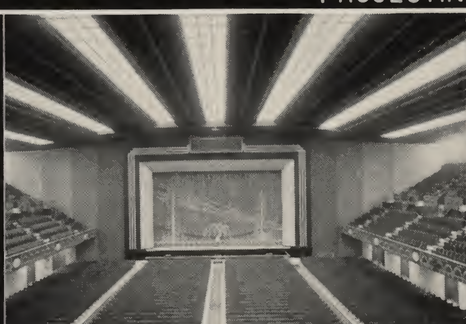
LOUVRED DOWNLIGHT EQUIPMENT



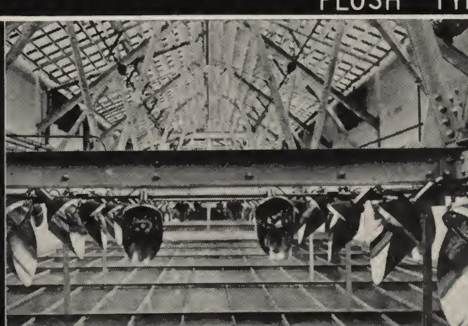
COMBINATION REFLECTOR-LENS CONTROL



PROJECTING TYPE DIFFUSING GLASS CEILING PANELS



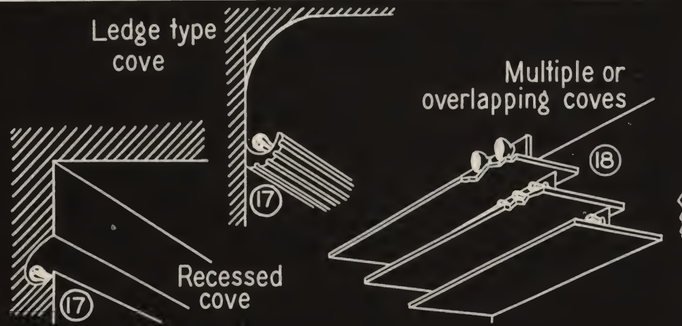
FLUSH TYPE PANELS OR SKYLIGHT SECTIONS



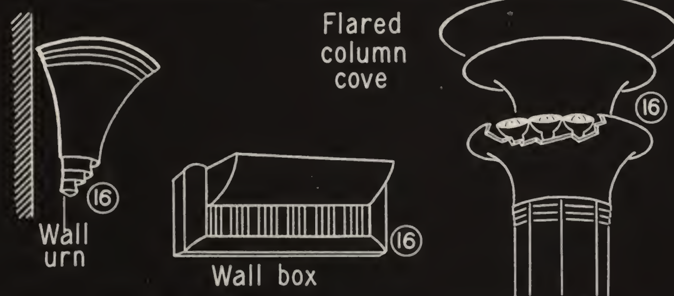
COMBINATION SKYLIGHTS - ARTIFICIAL AND NATURAL LIGHT

Figures in circles refer to corresponding classifications in the Coefficient of Utilization Tables

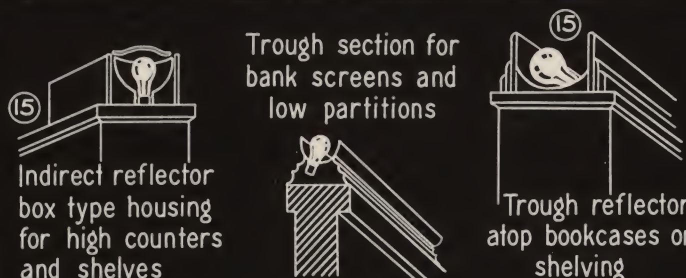
BUILT-IN INDIRECT LIGHTING METHODS



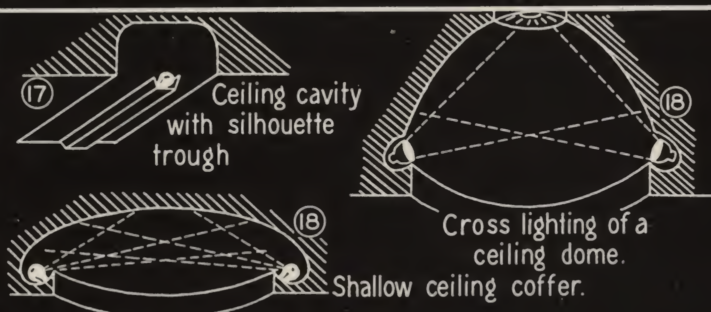
TYPICAL COVE SECTIONS



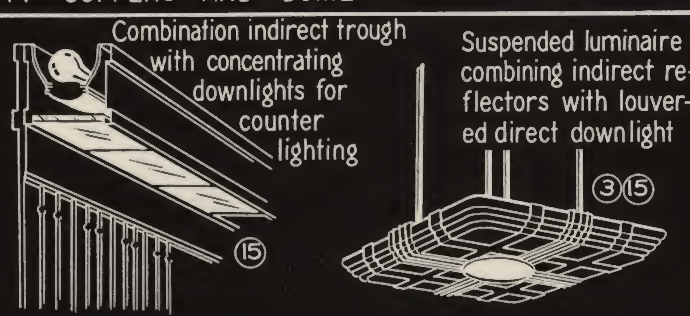
WALL URNS AND COLUMN COVES



SEMI-PORTABLE CONCEALED TROUGHS



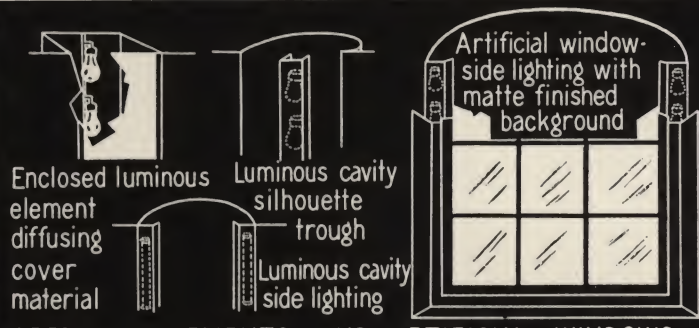
CEILING CAVITY - COFFERS AND DOMES



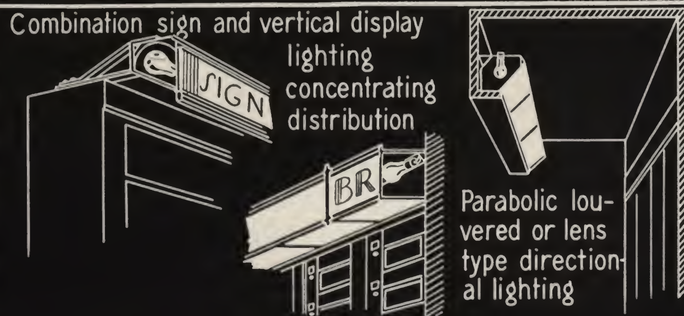
COMBINATION DIRECT - INDIRECT SYSTEMS

Figures in circles refer to corresponding classifications in the Coefficient of Utilization Tables

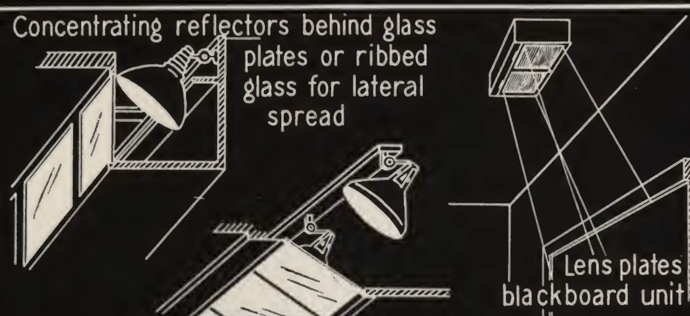
VERTICAL ELEMENTS - SIDEWALL LIGHTING- SPOTLIGHTING



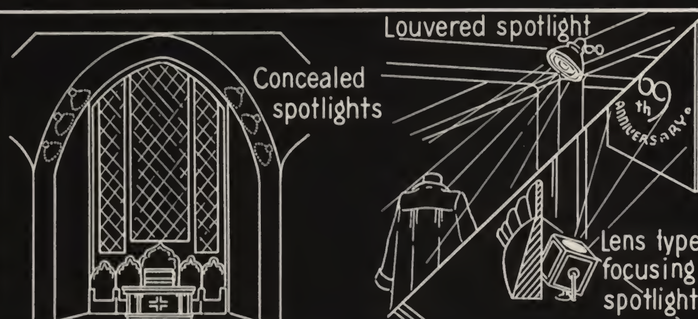
VERTICAL ELEMENTS AND ARTIFICIAL WINDOWS



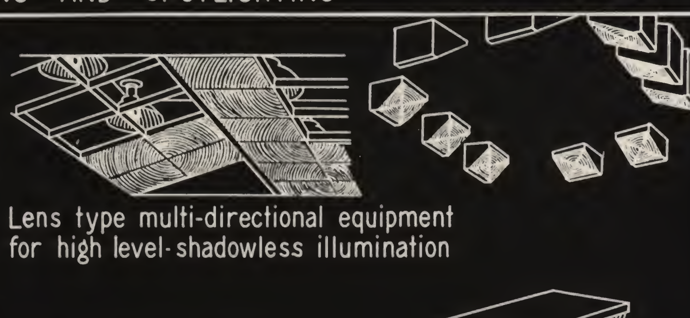
SHELVES - WALL CASES



DIRECTIONAL WALL DISPLAY LIGHTING



FLOODLIGHTING AND SPOTLIGHTING



MULTI-DIRECTIONAL SPOTLIGHTING

PART 2

GENERAL INTERIOR LIGHTING DESIGN

PART 2

GENERAL INTERIOR LIGHTING DESIGN

PART 2

GENERAL INTERIOR LIGHTING DESIGN

The problem of design for a strictly general lighting system involves five principal divisions:

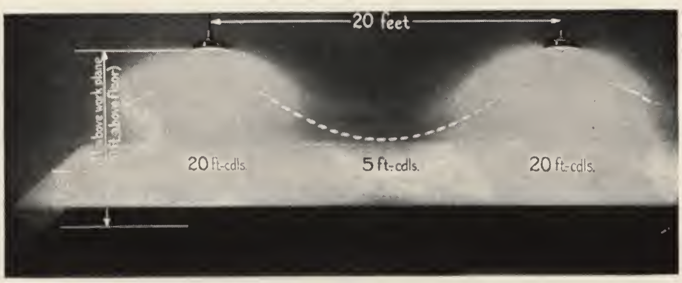
1. Decision as to footcandle level required—Table 1. (pages 8-11)
2. Layout of outlets or arrangement of light sources to provide substantially uniform illumination throughout the room. (pages 20-21)
3. Provision for adequate wiring to insure future capacity, convenient switching, and control. (pages 22-24)
4. Selection of reflecting equipment from the standpoint of efficiency, pleasing design, flexibility, and ease of maintenance. (pages 25, 28-31)
5. Computation of lamp size necessary to provide the footcandles of illumination desired. (pages 27-33)

SPACING—MOUNTING HEIGHT RELATIONS FOR UNIFORM LIGHTING

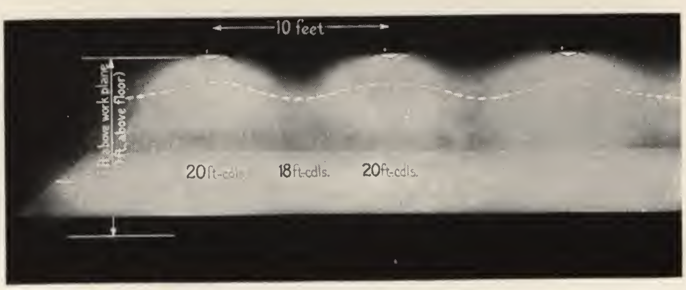
In planning a general lighting system the aim is to provide substantially a uniform level of illumination throughout the room. This eliminates spottiness, and dark corners, and makes the entire area equally suitable as a work space or for display, sales or whatever the general purpose may be.

The number of outlets to provide for any given area is determined by the maximum allowable spacing between lighting units and is in turn regulated by their height above the floor. The accompanying drawings illustrate this principle.

Strictly speaking, the spacing for uniform illumination on the work depends upon the height of the light source above the surface to be illuminated, but since most work surfaces are from 2½ to 3½ feet above the floor, the spacing may for practical purposes be considered a function of the mounting height of lamps above the floor. In general, a spacing in feet which does not substantially exceed this mounting height will result in reasonably uniform illumination.



Units spaced too far apart for their height furnish very uneven illumination, in this case a 4 to 1 variation, and work positions midway between units will be inadequately lighted; harsh shadows will also result. The remedy is to mount the units higher, or if that is impossible, to space them closer as illustrated below.



It will be noted that if the permissible ratio between spacing and mounting height is not exceeded, uniform illumination will be produced. Note also the overlapping of light which serves to eliminate shadows as the units are brought closer together.

The ceiling height, or rather the height which units may be mounted clear of obstructions, therefore limits the maximum permissible spacing.

The spacing of lighting units is not influenced by the size or type of lamp used, but is regulated by the distribution characteristics of the reflector. Table 2 gives the allowable spacing applicable to all common types of reflecting and diffusing equipment employed for general illumination purposes. Where less than the maximum permissible spacing is employed, the units may be mounted lower if desired but in no case should the mounting height be less than given in Table 2-A for the actual spacing used.

The spacing-mounting height relations apply not only to individual luminaires but equally so to the spacing between continuous or extended luminous beam panels, troughs or sections of coves. There are, however, some exceptions in the case of equipments giving especially concentrated or exceptionally widespread distribution of light:

Concentrating Louvered Downlights or Lens Plates provide varying degrees of concentration. The spacing between units to provide uniformity over a general area, or lengthwise of a counter or work table should be regulated by the actual distribution characteristics of the unit. In general, the usual purpose is fulfilled by a spacing about one-third to one-half the values given in Table 2.

Semi-indirect and Indirect Systems diffuse the light widely from the ceiling as a secondary source of large area and the spacing between units may be about two feet greater than indicated in Table 2.

Alternate Mercury and Incandescent Units in combination systems should provide a fair degree of uniformity with either system used alone, and should permit overlapping and blending of the light when used in combination. An alternate staggered layout with the spacing between units not to exceed .8 of the mounting height above the floor is recommended.

TABLE No. 2—ALLOWABLE SPACING BETWEEN LIGHT SOURCES

Ceiling Height (Or Height in the Clear)	Spacing Between Outlets		Spacing Between Outside Outlets and Wall		Approximate Area per Outlet (At Usual Spacings)
	Usual	Maximum (For Units at Ceiling)	Aisles or Storage Next to Wall	Desks, Workbenches, etc., Against Wall	
(Feet)	(Feet)	Not more than		Not more than	(Square Feet)
8	7	7½	Usually	3	50-60
9	8	8		3	60-70
10	9	9	one-half	3½	70-85
11	10	10½		3½	85-100
12	10-12	12	actual	3½-4	100-150
13	10-12	13		3½-4½	100-150
14	10-13	15	spacing	4-5	100-170
15	10-13	17		4-5	100-170
16	10-13	19	between	4-6	100-170
18	10-20	21		4-6	100-400
20 and up	18-24	24	units	5-7	300-500

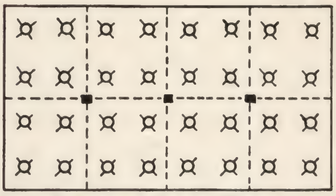
TABLE No. 2-A—MOUNTING HEIGHT OF LIGHT SOURCES

DIRECT AND SEMI-DIRECT LIGHTING UNITS				SEMI-INDIRECT AND INDIRECT LIGHTING	
Actual Spacing Between Units	Distance of Units from Floor Not Less Than	Desirable Mounting Height in Industrial Interiors	Desirable Mounting Height in Commercial Interiors	Actual Spacing Between Units	Recommended Suspension Length (Top of Bowl to Ceiling)
(Feet)	(Feet)			(Feet)	(Feet)
7	8	12 feet above floor if possible—to avoid glare, and still be within reach from stepladder for cleaning.	The actual hanging height should be governed largely by general appearance, but particularly in offices and drafting rooms, the minimum values shown in the second column should not be violated.	7	1-3
8	8½			8	1-3
9	9			9	1-3
10	10			10	1½-3
11	10½			11	2-3
12	11			12	2-3
14	12½	Where units are to be mounted much more than 12 feet it is usually desirable to mount the units at ceiling or on roof trusses.		14	2½-4
16	14			16	3-4
18	15			18	3-4
20	16			20	4-5
22	18			22	4-5
24	20			24	4-6

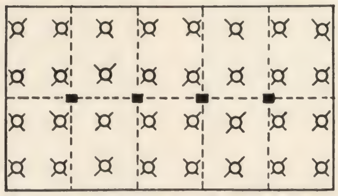
TYPICAL LAYOUTS

Closer spacing than indicated in Table 2 is often desirable in order to obtain a symmetrical layout in accordance with the arrangement of bays, columns, partitions, or other architectural features. These closer spacings will tend to improve uniformity as well as to reduce shadows at any given point. A few typical layouts of outlets are given below, not only to suggest architectural conformity but to suggest layouts to conform to machine arrangement.

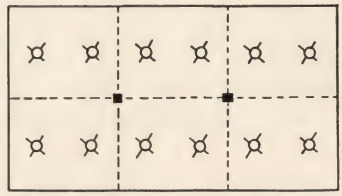
TO CONFORM WITH STRUCTURAL DESIGN



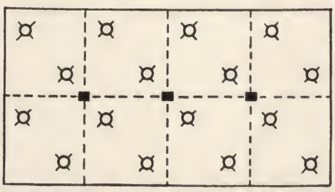
Four Units per Bay. This is the most common system for the square bay of usual dimensions.



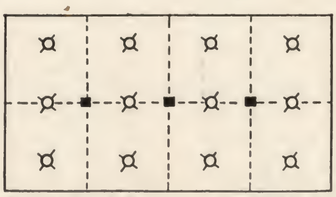
Four-Two System. Equivalent to three units per bay and alternative to four per bay where spacing allows.



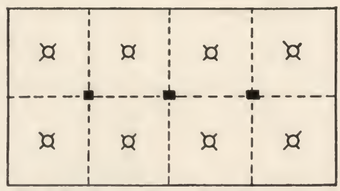
Two Units per Bay. Usually applicable only in narrow bays where the width is less than two-thirds the length.



Two Units per Bay—Staggered. Acceptable in larger interiors where permissible spacing does not dictate four per bay. Less favorable appearance and certain areas near walls may be inadequately lighted.

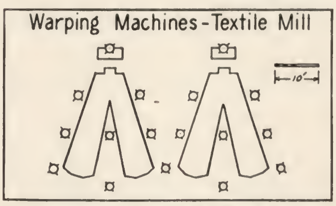


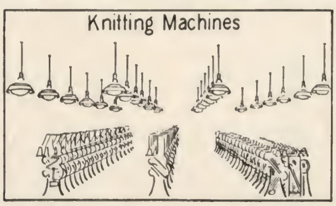
Interspaced Layout. Applicable in rectangular bays but suited only where the center row will not interfere with future structural changes such as added office partitions.

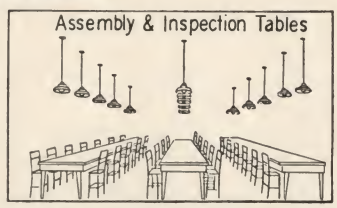


One Unit per Bay. Satisfactory only where the bay size is no greater than the maximum allowable spacing—an unusual condition except in high ceilinged rooms.

TO CONFORM WITH MACHINE ARRANGEMENT



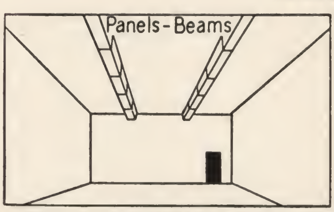


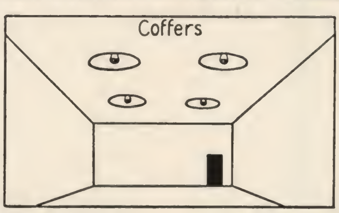


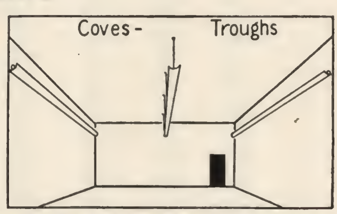
In industrial interiors with standard machine arrangement the general lighting system can best be arranged primarily with respect to the machine layout and secondarily with regard to structural features. Particularly in textile mills, paint, paper and printing industries and over special assembly and inspection tables, is it possible thus to favor the principal work surfaces and still achieve uniform lighting if the machinery were removed.

In factories having bulky machinery such as flour mills with intricate conveyor systems, carpet looms, furnaces, tanks, glass making, and others, which use specialized machinery, any plan of general lighting will encounter obstacles which will obstruct the light and prevent it from reaching important and vital points. The best arrangement for the general lighting should be studied and supplementary lighting applied wherever required.

BUILT-IN ARCHITECTURAL ELEMENTS







Where luminous panels, beams, coffers and coves are employed, individual and intimate treatment of different areas is required. The layout is concerned principally with architectural harmony and appearance. Such elements should however be so arranged and spaced as to produce appropriately uniform lighting for the visual requirements. Like conventional units, the spacing between individual elements should not exceed the values given in Table 2 if substantial uniformity is desired.

VOLTAGE AND LAMP ECONOMICS

The present wiring conditions in the majority of existing buildings of every character, and the restrictions and limitations they present in extending modern lighting, are so common as to preclude necessity of much discussion on the need for adequate wiring. Not only does the operation of lighting systems under poor wiring conditions prevent the user from obtaining the benefits of better lighting, but in many cases of overloaded circuits present operation is uneconomical to the extent that losses are suffered each year sufficient to pay for good wiring. Overloaded circuits are not only a nuisance from the standpoint of fuse trouble, which is indicative of a hazard, but unstable voltage conditions, which are inevitable, cause unsatisfactory performance of electrical devices. That a lighting customer pays for good wiring whether he has it or not is brought out clearly in the two charts below. Lamps operated below their rated voltage are inefficient in the production of light. Much current is wasted in heating the wires instead of being converted into light—the main purpose of the system. Where an attempt to correct this is made by substituting lower voltage lamps, some compensation is made, although this results in erratic performance of lamps, and early burnouts due to over-voltage operation when the load is reduced.

The conditions in Chart I are translated into cost in Chart II. This indicates a condition of under-voltage burning, where the unit cost of light has increased over 20%. In other words, the system is wasting more than 20 cents out of each dollar spent for lighting. Table 3 gives lamp characteristics.

CHART I

Voltage Drop

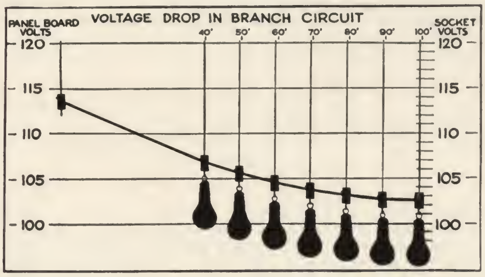


CHART II

Cost of Light

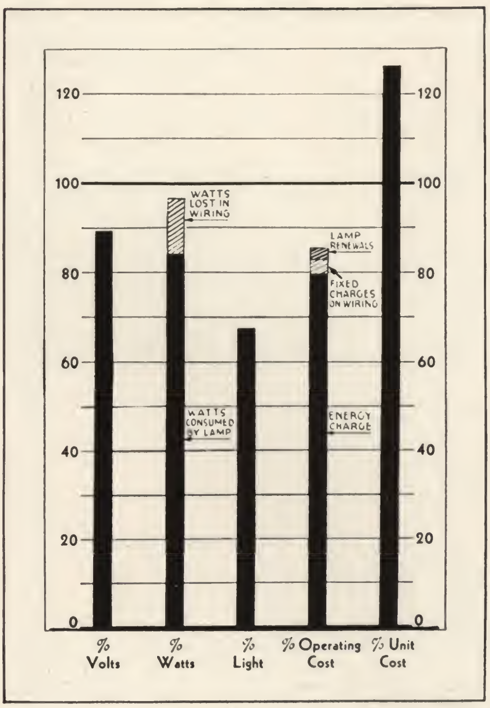


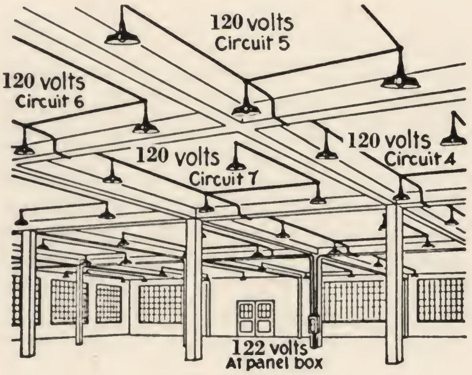
TABLE No. 3

Typical Performance of Large Incandescent Lamps Burned Below Rated Voltage

Note, for example, that 120-volt lamps burned on 115-volt circuits will deliver only 86.4% of their normal light output.

120-Volt Lamps Operated at (Volts)	% of Normal Voltage	% of Normal Light Output	% of Normal Watts	% of Normal Efficiency
120	100.0	100.0	100.0	100.0
119	99.2	97.3	98.8	98.2
118	98.3	94.4	97.4	96.9
117	97.5	91.8	96.1	95.4
116	96.7	89.2	95.0	93.8
115	95.8	86.4	93.6	92.3
114	95.0	84.0	92.4	90.8
113	94.2	81.5	91.2	89.4
112	93.3	78.0	89.8	87.7
111	92.5	76.6	88.7	86.2
110	91.7	74.1	87.5	84.8
108	90.0	69.5	85.0	81.7
106	88.3	65.0	82.5	79.4
104	86.7	60.8	80.3	75.8
102	85.0	56.6	77.9	72.8
100	83.3	52.0	75.5	69.7

GENERAL WIRING DATA



The National Electrical Code merely specifies wiring conditions with regard to fire hazard, with little consideration to economy of operation. The size of wire for a lighting installation may conform strictly to the Code and yet, because of length of circuit, produce excessive voltage drop with consequent inefficient lamp performance and unsatisfactory lighting.

On new or remodeling jobs where actual wattage to be installed is known, wiring specifications should be based on this load with capacity allowed for the next larger size lamps to be used in the future. In general, double the capacity can be installed initially at about one-third extra cost.

In those installations where transformers, feeders, panelboards and other electrical requirements must be estimated before the final lighting plans and resultant loads are determined, the best means for estimating is perhaps the common "watts per square foot" basis.

Such a basis is not exact, even though the level of illumination for various classes of occupancy or types of buildings may be fairly well established. One watt per square foot may produce from 3 to 10 footcandles depending on the size of the room, color of ceiling and walls, and type of lighting units or method of lighting employed. For that reason any "watts per square foot" load estimates should be based not alone on the footcandles to be provided but should be tempered always by knowledge of the utilization factors which so vitally affect the attainment of the desirable level. Following is a brief discussion of wattage allowance per square foot for various classes of interiors.

SUGGESTED "WATTS PER SQUARE FOOT" ALLOWANCE

1 Watt per Square Foot—For corridors, locker rooms, dead storage areas and inactive spaces where the illumination requirements are of the order of 5 footcandles. In factories, commercial buildings, and public interiors, it is often desirable to convert storage spaces into active work areas to meet immediate needs; it is recommended that such areas be wired for at least 2 watts per square foot.

2 Watts per Square Foot—Will provide for illumination levels of 10 to 15 footcandles in industrial areas, 8 to 12 in commercial areas with standard reflecting equipment. This order of illumination is the lower range of recommended values suitable for rough manufacturing work, packing, crating, storage and such areas occupied by mechanical and processing equipment where only casual and intermittent attention is required.

4 Watts per Square Foot—Minimum provision to attain average levels of 20 footcandles; recommended for schools, offices, stores and for the large proportion of general industrial areas. In large areas with direct lighting industrial reflectors, this allowance with a combination of favorable conditions would be sufficient for as high as 30 footcandles. In small offices or stores with indirect lighting this allowance would permit only 15 footcandles which represents the lower limits of modern practice, and is not sufficient for any future increase in the level of illumination.

6 Watts per Square Foot—Should be allowed as a minimum in all areas where general illumination of 30 footcandles is recommended but particularly in general offices, stores, and other commercial interiors. In small offices and similar small interiors such as sight-saving classrooms where indirect lighting would logically be used, even higher allowance should be made.

8 Watts per Square Foot—Rooms less than 20 x 20, typical of the small private office, lighted by modern indirect systems, require installed wattage of this order to attain the 30 to 35 footcandles that are being provided today. This order of wattage is also necessary for the many forms of louvered units, troughs and luminous architectural panel treatments where illumination of the order of 20 to 30 footcandles is desired.

Many of the more modern examples of lighting practice, where unusual treatment and lighting effect are desired, have as high as 12 to 15 watts per square foot installed. In the achievement of atmosphere and decorative effect, efficiency is of secondary importance and in such cases the actual illumination secured may be as low as 1 to 2 footcandles per watt per square foot as compared with 5 to 7 to be expected from conventional methods with average conditions prevailing.

TABLE No. 4—WIRE SIZE REQUIRED

Computed for Maximum of 2-Volt Drop on Two-wire, 120-Volt Circuits

Load per Circuit	Current 120-Volt Circuit	LENGTH OF RUN (Panel Box to Load Center)—Feet																			
Watts	Amps.	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
500	4.2	14	14	14	14	14	14	12	12	12	12	12	12	10	10	10	10	10	10
600	5.0	14	14	14	14	14	12	12	12	12	10	10	10	10	10	10	10	8	8
700	5.8	14	14	14	14	12	12	12	10	10	10	10	10	10	8	8	8	8	8
800	6.7	14	14	14	12	12	12	10	10	10	10	10	8	8	8	8	8	8	8
900	7.5	14	14	12	12	12	10	10	10	10	8	8	8	8	8	8	8	8	6
1000	8.3	14	14	12	12	10	10	10	10	10	8	8	8	8	8	8	6	6	6
1200	10.0	14	12	12	10	10	10	10	8	8	8	8	8	6	6	6	6	6	6
1400	11.7	14	12	10	10	10	8	8	8	8	8	6	6	6	6	6	6	6	6
1600	13.3	12	12	10	10	8	8	8	8	6	6	6	6	6	6	6	6	4	4
1800	15.0	12	10	10	10	8	8	8	6	6	6	6	6	6	4	4	4	4	4
2000	16.7	12	10	10	8	8	8	6	6	6	6	6	6	4	4	4	4	4	4
2200	18.3	12	10	10	8	8	8	6	6	6	6	6	4	4	4	4	4	4	2
2400	20.0	10	10	8	8	8	6	6	6	6	6	4	4	4	4	4	4	2	2
2600	21.7	10	10	8	8	6	6	6	6	4	4	4	4	4	4	4	4	2	2
2800	23.3	10	8	8	8	6	6	6	6	4	4	4	4	4	4	4	2	2	2
3000	25.0	10	8	8	6	6	6	6	6	4	4	4	4	4	4	2	2	2	2
3500	29.2	10	8	8	6	6	6	4	4	4	4	2	2	2	2	2	2	2	2
4000	33.3	8	8	6	6	6	4	4	4	4	2	2	2	2	2	2	1	1	1
4500	37.5	8	6	6	6	4	4	4	2	2	2	2	2	2	1	1	1	1	1

WIRING RECOMMENDATIONS

Branch Circuits for General Illumination (2 Volts Maximum Drop Panelboard to Outlets)

Load and Length of Run. For 15 amp. circuits the initial load per circuit should not exceed 1000 watts with No. 12 minimum wire size to be used where length of run does not exceed 50 feet; No. 10 wire for runs between 50 and 100 feet; No. 8 wire for runs between 100 and 150 feet.

For heavy duty lamp circuits (the National Electrical Code permits 8 mogul sockets, 40 amperes per circuit) 3000 watts with No. 8 wire up to 50 foot runs; No. 6 wire 50 to 100 foot runs; No. 4 wire for runs from 100 to 150 feet. It is recommended that panelboards be so located that the length of run does not exceed 100 feet, if practical to do so.

Panelboards—One spare circuit should be provided for each five circuits used in the initial installation. Concealed branch circuit conduit should be large enough for one additional circuit for every five or less circuits it contains.

Service and Feeders (Maximum feeder drop—2 Volts)—The carrying capacity of service wiring and feeders should be sufficient for the normal branch circuit load with no more than a 2-volt drop. Normal diversity of branch circuit load in many cases reduces required feeder capacity below the actual total branch circuit load; the National Electrical Code allowances for this demand factor should govern. Provision should be made for increasing feeder capacity to take care of next larger lamp size (50% increase) than installed initially.

Convenience Outlets for Lighting—Should not be connected to branch circuits which supply fixture outlets as a part of the general illumination system. No wire smaller than No. 12 should be used; No. 10 if the length of run exceeds 100 feet.

In *Office Space* there should be one convenience outlet circuit for each 800 square feet of floor area with at least one duplex outlet for each 20 linear feet of wall.

In *Manufacturing Spaces* there should be one convenience outlet for each 1200 square feet or fraction of floor space with at least one duplex outlet in each bay.

In *Stores* there should be at least one convenience outlet in each supporting column or at least one floor outlet for each 400 square feet or fraction of floor space. For windows, at least one outlet for each 5 linear feet of plate glass, with an additional floor outlet for each 50 square feet of platform area. Provision for sign should be made by installing a 1-inch conduit from the distribution panel to the front face of the building for each individual store space.

SELECTION OF LIGHTING EQUIPMENT

It is obviously impossible to discuss in detail or to classify the hundreds of different lighting equipments listed in equipment manufacturers' catalogs. New equipment and new designs are continually coming on the market, which embody new materials, new styling or new concepts of application. Fundamentally, each falls into one of the general classifications shown on pages 28 and 30.

The selection of one type of lighting over another is largely a matter of suitability and preference, tempered always by an understanding of the general characteristics of each type of system.

In the choice of both the general type of lighting system and finally in the selection of competitive equipment of a given type, the following questions are pertinent:

1. Will it be Comfortable without Annoyance from Direct Glare?

Difficult to appraise quantitatively since acceptable brightness limits depend upon the character of installation, seeing requirements, casual or prolonged exposure; for casual viewing permissible brightness within the normal field of view should not exceed 1500 foot-lamberts; for prolonged exposure such as office work not more than 500 foot-lamberts for the brightest square inch. Minimum contrast of the lighted units against the background is also important.

2. Will it Minimize Reflected Glare?

Well-shielded direct lighting units may be free from direct glare or uncomfortable brightness, but may cause uncomfortable and distracting bright highlights reflected from shiny or polished furniture, desk, or counter tops, or material worked on; this calls for highly diffused or large area, low brightness sources, or careful attention to proper location of units.

3. Is it Reasonably Efficient for the Purpose?

Broadly, efficiency is measured by over-all satisfactoriness or achievement of effect. Competitively, the problem is always the balance between initial cost and operating expense over a reasonable period and involves specific and comparative cost figures.

4. Will Vertical and Oblique Surfaces be Well Lighted?

Supplementary lighting will generally be necessary where such planes need predominant lighting. Where dependence is placed on general lighting, as in the case of most stores, units giving wide angle distribution such as white glass diffusing globes or prismatic enclosing globes having extensive light distribution will produce a much higher illumination on vertical or oblique surfaces than where concentrating downlights or even indirect lighting are employed.

5. Will There be Harsh Shadows?

An important consideration in drafting rooms, and industries where machinery is likely to cast concealing shadows. Shadows are minimized by large area diffusing sources, or by proper location of units so that the illumination at any given point is contributed to by several sources.

6. Is it Easy to Clean and Maintain?

Lighting systems depreciate quickly due to dust and dirt, and lamp replacements are inevitable. An extremely important consideration is the balance of the cost of maintenance against waste of electric energy due to depreciation. Types of systems vary widely and between competitive equipment, ease of maintenance should receive high ranking.

7. Will it Meet any Special Requirements as to Color Quality?

Sometimes a psychological question of atmosphere and surroundings; in industrial applications it is more often a question of matching seeing habits.

Utilization Efficiency of Various Types of Equipment

The infinite variety of equipment with slight differences in output, distribution, and with various adjustment and control accessories presents almost endless combinations which affect the actual utilization. However, the 18 classifications for which Coefficients of Utilization have been computed present a wide diversity of conditions from direct to indirect, and the range is adequate for usual practical calculation requirements.

Detailed analysis and comparison of specific reflecting equipments can be made accurately only by a study of their actual distribution curves, and from which specific Coefficients of Utilization can be derived. The use of Table 6 imposes the necessity of knowing approximately the output efficiency and distribution characteristics of the reflecting equipment under consideration in order to select the group to which it most nearly applies.

PROCEDURE IN LIGHTING CALCULATIONS

In order to specify the lamp size necessary to provide the footcandles desired, the first step is to determine the percentage of light emitted by the lamp that actually gets down to and is useful on the working level. This percentage is called the Coefficient of Utilization for the particular installation and is given in Table 6 for a wide range of conditions.

A simple "watts per square foot" specification is unreliable unless applied with the benefit of experienced judgment of all the various factors which affect the result. The principal variables are discussed briefly below and each is taken into account in arriving at the Coefficient of Utilization.

Having classified the room proportions (Room Index, Table 5) and obtained the Coefficient of Utilization from Table 6 for the particular type of installation and equipment employed, the lamp size or lumen output can be computed from the formula on page 32, substituting in the formula the square feet per outlet according to the actual layout and using whatever depreciation factor that seems to fit the actual conditions of maintenance.

Table 7 giving *computed values* will be found helpful in eliminating computations in all cases where these general circumstances apply.

ROOM INDEX

In general, large rooms use light more efficiently than do small rooms because there is less wall area to absorb light in proportion to the floor space. For the same reason rooms with high ceilings are less efficiently lighted than low-ceilinged rooms with the same arrangement of floor space.

Table 5 classifies room proportions into ten classes as indicated by letters A to J. This serves merely as a reference index to be applied in Table 6 for the particular type of reflecting equipment used. Note that this factor of room size and proportion may influence the Coefficient of Utilization from 100 to nearly 300 per cent, depending on the type of reflecting equipment.

REFLECTOR CHARACTERISTICS

The selection of reflecting equipment depends not only upon its efficiency but also upon suitable distribution of light. Coefficients of Utilization are computed from the candlepower distribution curves in accordance with basic experimental data. It will be quite evident that a narrow or concentrating distribution will direct the light strongly downward keeping less of it from striking the walls and ceiling than will a broad distribution. In the former case the influence of the size of room or the color of walls and ceiling on the utilization is much less than the latter case where a large proportion of light strikes the walls and ceiling from which only a part is re-reflected to working surfaces.

INTERIOR FINISH

Coefficients of Utilization also coordinate the effect of interior finish on lighting results, and the Tables embrace a range of general ceiling and wall reflection conditions. The color chart in this publication shows a wide range of colors and interior finishes giving the reflection factor or percentage of light from Mazda lamps which each color reflects. The values will change somewhat for other sources depending upon their spectral quality.

Note in Table 6 that the influence of the interior finish is least important with direct reflectors, becoming increasingly influential with semi-direct lighting and a major factor in lighting efficiency with semi-indirect and indirect lighting. The net reflection value of even light walls seldom exceeds 50% when allowance is made for wall furnishings and door and window openings. In glass-enclosed rooms or buildings the effective wall reflection is practically negligible.

MAINTENANCE FACTOR

Allowance must always be made for depreciation of lamps, reflectors and reflecting surfaces so that desired footcandle levels may be maintained in service as contrasted to initial values. Lamps average about 85 to 90% of their initial lumen output and the inevitable film of dust that collects quickly on reflecting surfaces accounts for another 10 to 20% normal depreciation even with a reasonable cleaning schedule. The average illumination maintained in service will, under average conditions, be of the order of 70% of the initial value, or .70 when expressed as a *maintenance factor*. In some instances, particularly with direct lighting equipment where there is little dust and smoke in the atmosphere, a higher maintenance value may be obtained, but in the case of open indirect equipment, cove lighting, skylights and similar types of installations hard to reach and likely to be neglected, a considerably lower maintenance factor should be assumed as indicated in Table 6.

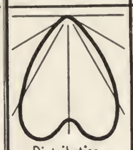
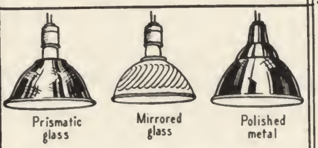
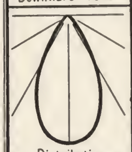
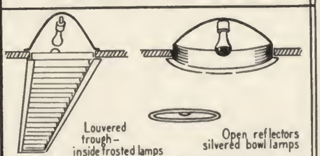
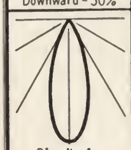
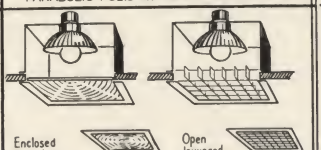
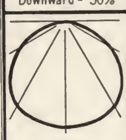
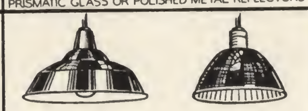
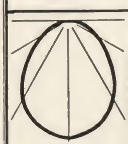
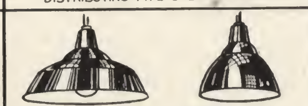
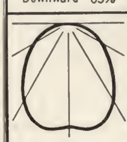
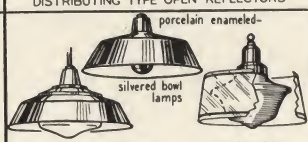
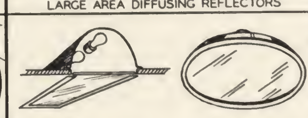
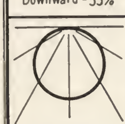
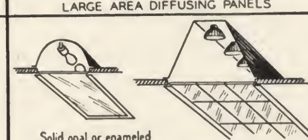
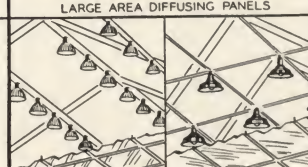
TABLE No. 5—ROOM INDEX*

(Classification of rooms according to their proportions)

		CEILING HEIGHT—FEET										
For Semi-Indirect and Indirect Lighting		9 and 9½	10 to 11½	12 to 13½	14 to 16½	17 to 20	21 to 24	25 to 30	31 to 36	37 to 50		
		MOUNTING HEIGHT ABOVE FLOOR—FEET										
For Direct and Semi-Direct Lighting		7 and 7½	8 and 8½	9 and 9½	10 to 11½	12 to 13½	14 to 16½	17 to 20	21 to 24	25 to 30	31 to 36	37 to 50
Room Width (Feet)	**Room Length (Feet)**	ROOM INDEX										
9 (8½–9)	8-10	H	I	J	J							
	10-14	H	I	I	J							
	14-20	G	H	I	J	J						
	20-30	G	G	H	I	J	J					
	30-42	F	G	H	I	J	J	J				
	42-up	E	F	G	H	I	J	J				
10 (9½–10½)	10-14	G	H	I	J	J						
	14-20	G	H	I	J	J	J					
	20-30	F	G	H	I	J	J					
	30-42	F	G	G	H	I	J	J				
	42-60	E	F	G	H	I	J	J				
	60-up	E	F	F	H	H	I	J				
12 (11–12½)	10-14	G	H	I	I	J	J					
	14-20	F	G	H	I	J	J					
	20-30	F	G	G	H	I	J	J				
	30-42	E	F	G	H	I	J	J				
	42-60	E	F	F	G	H	I	J				
	60-up	E	E	F	G	H	I	J				
14 (13–15½)	14-20	F	G	H	H	I	J	J				
	20-30	E	F	G	H	I	J	J				
	30-42	E	F	F	G	H	I	J	J			
	42-60	E	E	F	F	H	I	J	J	J		
	60-90	D	E	E	F	G	H	J	J	J		
	90-up	D	E	E	F	F	G	I	J	J		
17 (16–18½)	14-20	E	F	G	H	I	J	J				
	20-30	E	F	F	G	H	I	J				
	30-42	D	E	F	G	H	H	J	J	J		
	42-60	D	E	E	F	G	G	I	J	J	J	
	60-110	D	E	E	F	G	G	I	J	J	J	
	110-up	C	D	E	E	F	G	H	I	J	J	
20 (19–21½)	20-30	D	E	F	G	H	I	J	J			
	30-42	D	E	E	F	G	H	I	J	J		
	42-60	D	D	E	E	F	G	I	J	J	J	
	60-90	C	D	E	E	F	G	H	J	J	J	
	90-140	C	D	D	E	F	F	H	I	I	J	J
	140-up	C	D	D	E	F	F	H	H	I	J	J
24 (22–26)	20-30	D	E	E	F	G	H	I	J	J		
	30-42	C	D	E	F	G	G	I	J	J		
	42-60	C	D	D	E	F	G	H	I	J	J	
	60-90	C	D	D	E	F	F	H	I	J	J	J
	90-140	C	C	D	E	E	F	G	H	I	J	J
	140-up	C	C	D	E	E	F	G	H	I	I	J
30 (27–33)	30-42	C	D	D	E	F	G	H	I	J	J	
	42-60	C	C	D	D	F	F	H	H	I	J	
	60-90	B	C	C	D	E	F	G	H	I	J	J
	90-140	B	C	C	D	E	E	F	G	H	I	J
	140-180	B	C	C	D	E	E	F	G	H	I	J
	180-up	B	C	C	D	E	E	F	G	H	I	J
36 (34–39)	30-42	B	C	D	E	F	F	H	I	I	J	
	42-60	B	C	C	D	E	F	G	H	I	J	J
	60-90	A	C	C	C	E	E	F	H	H	J	J
	90-140	A	B	C	C	D	E	F	G	H	I	J
	140-200	A	B	C	C	D	E	F	F	G	H	I
	200-up	A	B	C	C	D	E	F	F	G	H	I
42 (40–45)	42-60	A	B	C	C	E	F	G	H	I	I	J
	60-90	A	B	B	C	D	E	F	G	H	I	J
	90-140	A	B	B	C	D	D	E	F	G	H	J
	140-200	A	A	B	C	D	D	E	F	G	H	I
	200-up	A	A	B	C	D	D	E	F	F	G	I
50 (46–55)	42-60	A	A	B	C	D	E	F	G	H	I	J
	60-90	A	A	B	C	C	D	F	F	G	H	J
	90-140	A	A	A	C	C	D	E	F	F	G	I
	140-200	A	A	A	C	C	D	E	E	F	G	I
	200-up	A	A	A	C	C	D	E	E	F	G	H
60 (56–67)	60-90	A	A	A	B	C	D	E	F	G	H	I
	90-140	A	A	A	B	C	C	D	E	F	G	H
	140-200	A	A	A	B	C	C	D	E	E	F	H
	200-up	A	A	A	B	C	C	D	E	E	F	H
75 (68–90)	60-90	A	A	A	A	B	C	D	E	F	G	I
	90-140	A	A	A	A	B	C	D	E	F	F	H
	140-200	A	A	A	A	B	B	C	D	E	F	G
	200-up	A	A	A	A	B	B	C	D	E	F	G
90 or more	60-90	A	A	A	A	B	C	D	E	F	G	H
	90-140	A	A	A	A	A	B	C	D	E	F	G
	140-200	A	A	A	A	A	B	C	D	E	F	G
	200-up	A	A	A	A	A	B	C	C	D	E	F

* In former publications, Room Index was shown numerically comprising ten classifications from 0.6 to 5.0. The letter designations in this table are merely substitutions of letters for numbers. A represents the highest room index formerly represented by 5.0; B, 4.0 and so on down to J which is equivalent to 0.6.

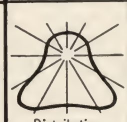
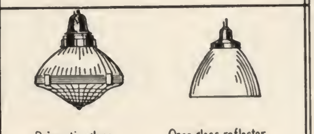
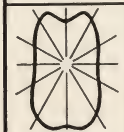
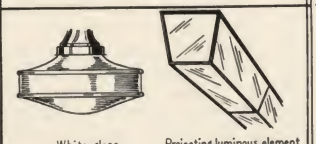
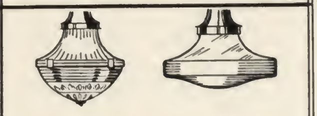
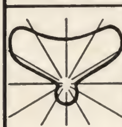
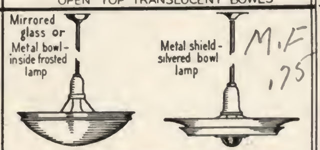
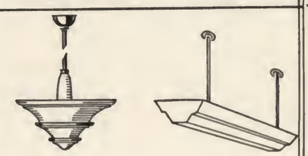
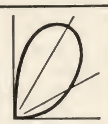
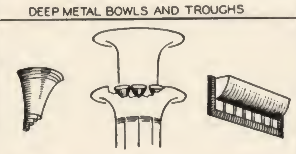
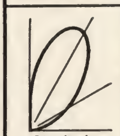
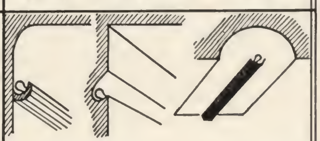
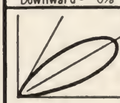
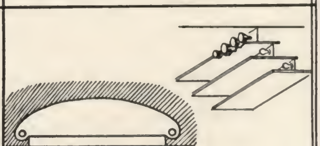
TABLE No. 6—COEFFICIENTS OF UTILIZATION

Class	Type	Type of Distribution and Efficiency Classification	Typical Equipment Representative of Each Group	Ceiling	75%			50%			30%	
				Walls	**50%**	**30%**	**10%**	**50%**	**30%**	**10%**	**30%**	**10%**
				Room Index	**COEFFICIENTS OF UTILIZATION**							
DIRECT — CONCENTRATING TYPES	1	 Distribution Downward - 70%	 Prismatic glass; Mirrored glass; Polished metal — HIGH BAY OPEN REFLECTORS	J	.40	.38	.36	.39	.38	.36	.39	.36
				I	.48	.46	.46	.47	.46	.45	.46	.43
				H	.51	.51	.50	.50	.50	.49	.50	.48
				G	.55	.54	.54	.54	.52	.52	.52	.51
				F	.58	.56	.55	.55	.55	.54	.55	.53
				E	.60	.59	.58	.59	.58	.57	.57	.56
				D	.64	.61	.60	.62	.60	.60	.60	.59
				C	.65	.63	.61	.63	.62	.60	.60	.60
				B	.65	.64	.63	.64	.62	.62	.62	.61
				A	.66	.65	.64	.64	.63	.62	.62	.62
	2	 Distribution Downward - 50%	 Louvered trough— inside frosted lamps; Open reflectors silvered bowl lamps — PARABOLIC POLISHED METAL REFLECTORS	J	.29	.27	.26	.28	.27	.26	.28	.26
				I	.34	.33	.32	.34	.32	.32	.32	.31
				H	.37	.36	.36	.36	.36	.35	.36	.34
				G	.39	.39	.38	.38	.38	.37	.38	.36
				F	.41	.40	.39	.40	.39	.38	.39	.38
				E	.43	.42	.42	.42	.42	.40	.41	.40
				D	.46	.44	.43	.44	.43	.42	.42	.42
				C	.46	.45	.44	.45	.44	.43	.43	.42
				B	.47	.46	.45	.46	.44	.44	.44	.44
				A	.47	.46	.46	.46	.45	.44	.44	.44
	3	 Distribution Downward - 30%	 Enclosed lens plate; Open louvered — PRISMATIC GLASS OR POLISHED METAL REFLECTORS	J	.17	.16	.16	.17	.16	.16	.17	.15
				I	.21	.20	.20	.20	.20	.19	.20	.19
				H	.22	.22	.21	.22	.21	.21	.21	.21
				G	.24	.23	.23	.23	.22	.22	.22	.22
				F	.25	.24	.24	.24	.23	.23	.23	.23
				E	.26	.25	.25	.25	.25	.24	.25	.24
				D	.27	.26	.26	.26	.26	.26	.26	.25
				C	.28	.27	.26	.27	.26	.26	.26	.26
				B	.28	.27	.27	.27	.27	.26	.26	.26
				A	.28	.28	.27	.28	.27	.27	.27	.26
DIRECT — DISTRIBUTING TYPES	4	 Distribution Downward - 75%	 RLM Dome porcelain enameled- inside frosted lamp; Mirrored or prismatic glass- inside frosted lamp — DISTRIBUTING TYPE OPEN REFLECTORS	J	.34	.29	.24	.34	.29	.24	.28	.24
				I	.42	.38	.34	.42	.37	.33	.37	.33
				H	.46	.43	.39	.45	.42	.39	.42	.39
				G	.50	.47	.43	.49	.46	.43	.45	.42
				F	.53	.50	.46	.52	.49	.46	.48	.45
				E	.58	.55	.51	.57	.54	.51	.53	.51
				D	.62	.59	.56	.61	.58	.56	.58	.56
				C	.64	.61	.58	.63	.60	.58	.60	.58
				B	.67	.65	.63	.66	.64	.62	.63	.61
				A	.69	.67	.65	.67	.66	.64	.65	.63
	5	 Distribution Downward - 65%	 RLM Dome porcelain enameled- white bowl lamp; RLM Deep bowl porcelain enameled- inside frosted lamp — DISTRIBUTING TYPE OPEN REFLECTORS	J	.32	.28	.25	.32	.28	.25	.27	.25
				I	.40	.36	.34	.39	.35	.33	.35	.33
				H	.43	.39	.37	.42	.39	.37	.39	.37
				G	.46	.43	.41	.45	.43	.41	.43	.41
				F	.48	.45	.43	.47	.45	.43	.45	.43
				E	.52	.50	.48	.51	.49	.47	.49	.47
				D	.56	.54	.52	.55	.53	.51	.53	.51
				C	.57	.55	.53	.56	.54	.52	.54	.52
				B	.60	.58	.56	.59	.57	.55	.57	.55
				A	.61	.59	.57	.60	.58	.57	.58	.56
	6	 Distribution Downward - 60%	 porcelain enameled- silvered bowl lamps; RLM Glassteel diffuser clear lamp; Enclosing globe parchment shade — LARGE AREA DIFFUSING REFLECTORS	J	.29	.24	.21	.28	.24	.21	.23	.21
				I	.36	.32	.29	.35	.31	.28	.30	.28
				H	.39	.36	.33	.38	.35	.33	.34	.32
				G	.43	.39	.36	.41	.38	.36	.37	.35
				F	.45	.42	.39	.43	.40	.38	.39	.38
				E	.49	.46	.44	.47	.45	.43	.43	.42
				D	.53	.50	.47	.51	.48	.46	.47	.46
				C	.54	.52	.49	.52	.50	.48	.48	.47
				B	.57	.55	.53	.55	.52	.51	.51	.50
				A	.59	.56	.54	.56	.54	.52	.52	.51
	7	 Distribution Downward - 55%	 Extended trough reflector cased opal glass cover; Enameled metal reflector with diffusing cover plate — LARGE AREA DIFFUSING PANELS	J	.26	.22	.19	.25	.22	.19	.21	.19
				I	.32	.29	.26	.31	.28	.26	.28	.26
				H	.35	.32	.30	.34	.32	.30	.31	.30
				G	.38	.35	.33	.37	.35	.32	.34	.32
				F	.40	.37	.35	.38	.36	.35	.36	.35
				E	.43	.41	.39	.42	.40	.38	.40	.38
				D	.46	.44	.42	.45	.43	.42	.43	.42
				C	.48	.46	.43	.46	.45	.43	.44	.43
				B	.50	.48	.46	.48	.47	.46	.46	.45
				A	.51	.49	.48	.50	.48	.47	.47	.46
	8	 Distribution Downward - 40%	 Solid opal or enameled glass cover; Enclosed skylight — LARGE AREA DIFFUSING PANELS	J	.19	.16	.14	.18	.16	.14	.16	.14
				I	.23	.21	.19	.23	.20	.19	.20	.19
				H	.25	.23	.22	.25	.23	.22	.23	.22
				G	.27	.25	.24	.27	.25	.24	.24	.24
				F	.29	.27	.25	.28	.26	.25	.26	.25
				E	.31	.30	.28	.31	.29	.28	.29	.28
				D	.34	.32	.30	.33	.32	.30	.31	.30
				C	.35	.33	.32	.34	.32	.32	.32	.31
				B	.36	.35	.34	.35	.34	.33	.34	.33
				A	.37	.36	.35	.36	.35	.34	.34	.34
	9	 Distribution Downward - 25%	 COMBINATION SKYLIGHT	J	.12	.10	.09	.12	.10	.09	.10	.09
				I	.14	.13	.12	.14	.13	.12	.13	.12
				H	.16	.15	.14	.16	.14	.14	.14	.14
				G	.17	.16	.15	.17	.16	.15	.15	.15
				F	.18	.17	.16	.18	.16	.16	.16	.16
				E	.20	.19	.18	.19	.18	.18	.18	.18
				D	.21	.20	.19	.20	.20	.19	.20	.19
				C	.22	.21	.20	.21	.20	.20	.20	.20
				B	.23	.22	.21	.22	.21	.21	.21	.20
				A	.23	.22	.22	.22	.22	.21	.22	.21

Note: The Coefficients of Utilization are calculated for the specific light output and distribution characteristics shown at the left of the opposite page. Equipments illustrated are typical and are not intended to represent the specific performance of any manufacturer's product. The **Light output range** given below indicates variations to be expected between commercial equipments falling in any one of the several classifications, for which coefficients will be in proportion to the actual light output.

MAINTENANCE FACTOR Average Conditions	Factors Influencing the Selection of the Lighting Equipment
.70	**Light output range**—68 to 75%. **Source brightness**—low at normal angles of view because of large shielding angle. **F.C. on Vertical**—fair. **Reflected glare**—likely to be severe because of reflected source brightness. ¶ Enameled reflectors of this shape do not produce a concentrated distribution and should not be confused with high bay reflectors.
.70	**Light output range**—45 to 60% depending on louver design and reflector size. Coefficients are calculated for 50% output. Louvered troughs are likely to average 10% less, open silvered bowl lamp units may range from 10 to 20% higher than the values shown. Specular surface parabolic reflectors essential. **Source brightness**—very low at normal angles of view. **F. C. on Vertical**—relatively low. **Reflected glare**—likely to be severe with the louvered equipment. ¶ An effective means of securing high level illumination with low brightness contrasts.
.70	**Light output range**—27 to 35%—depending on adjustment or type of louver used. Specular surface parabolic reflectors are essential. **Source brightness**—low. **F.C. on Vertical**—extremely low. Care must be taken in location of units to avoid reflected glare from polished surfaces. ¶ Adaptable to many applications in combination with a fair proportion of indirect lighting. Lens plate units designed for wider distribution will have a higher output and fall in Group 2.
.75	**Light output range**—75% for RLM Dome; 70 to 80% from extensive distribution prismatic or mirrored reflectors. **Source brightness**—uncomfortably high unless mounted either above 20 feet or below eye level so that reflector shields the bright filament. **F.C. on Vertical**—fairly high. **Reflected glare**—extremely severe from polished surfaces. ¶ Highly efficient but limited in application to locations where conditions permit avoidance of direct and reflected glare.
.75	**Light output range**—63 to 68%. **Source brightness**—moderately high but acceptably good for moderate levels of general illumination. **F.C. on Vertical**—fairly high. Reflected glare—considerably less than clear lamp units—the dome rating better than the deep bowl shape. ¶ The RLM—white bowl lamp combination particularly, suitably meets a variety of industrial lighting requirements.
.70	**Light output range**—The standard Glassteel 60% down, 7% up; the silvered bowl lamp and reflector 60 to 65% down, no upward light; the shaded enclosing globe 50% down, 20% up; coefficients of utilization all about the same. **Source brightness**—relatively low. **F.C. on Vertical**—moderately high. **Reflected glare**—suitably low for most industrial requirements. ¶ A group of equipment essential to high quality industrial lighting.
.70	**Light output range**—50 to 60% depending on reflector efficiency and transmission of glass cover plates. Coefficients of utilization based on 55%. **Source brightness**—generally low, and controllable by increasing area; brightness limits for comfort range from 400 to 1000 foot-lamberts. Supplementary indirect lighting is often used to relieve brightness contrasts against an otherwise dark ceiling.
.65	This group is classified separately only because of lower light output. **Light output range**—35 to 45%, depending on construction and transmitting material; with extra heavy solid opal glass or low transmission plastics, the efficiency range may extend to even lower limits. Coefficients of utilization based on 40%. **Source brightness**—controllable by source area and diffusion. The size and disposition of luminous panels and artificial skylight sections are matters largely regulated by architectural composition.
.60	**Light output range**—May vary over a considerable range depending on construction features and type of glass used. Coefficients of utilization based on 25%. Skylights serving both natural and artificial lighting penalize efficiency because there is no help from multiple reflections. Skylight framing and mullions and mechanical control devices likewise lessen efficiency. Quality factors with respect to direct and reflected glare and shadows are highly favorable.

TABLE No. 6—COEFFICIENTS OF UTILIZATION

		Type of Distribution and Efficiency Classification	Typical Equipment Representative of Each Group	Ceiling	75%			50%			30%	
				Walls	50%	30%	10%	50%	30%	10%	30%	10%
				Room Index	Coefficients of Utilization							
SEMI-DIRECT	10	 Distribution Upward - 25% Downward - 55%	 Prismatic glass enclosing unit; Open glass reflector white bowl lamp	J	.29	.24	.22	.27	.23	.21	.22	.20
				I	.35	.31	.29	.33	.29	.27	.28	.26
				H	.39	.35	.33	.36	.33	.31	.31	.29
				G	.43	.39	.36	.39	.36	.34	.34	.32
				F	.46	.42	.38	.42	.39	.36	.37	.34
				E	.50	.46	.43	.46	.43	.40	.40	.37
				D	.54	.49	.46	.49	.46	.43	.43	.41
				C	.56	.52	.48	.51	.48	.45	.45	.42
				B	.60	.56	.52	.54	.50	.48	.47	.45
				A	.62	.58	.55	.56	.52	.50	.49	.47
SEMI-DIRECT	11	 Distribution Upward - 35% Downward - 45%	 White glass enclosing globe; Projecting luminous element cased opal panels	J	.24	.20	.17	.22	.18	.16	.16	.14
				I	.30	.25	.23	.27	.23	.20	.21	.19
				H	.34	.29	.26	.30	.26	.24	.24	.22
				G	.37	.33	.30	.33	.29	.27	.27	.25
				F	.41	.36	.32	.36	.32	.29	.29	.27
				E	.45	.41	.37	.40	.36	.33	.32	.30
				D	.49	.44	.40	.43	.39	.36	.35	.33
				C	.52	.47	.43	.45	.41	.38	.37	.35
				B	.55	.51	.47	.48	.44	.42	.40	.38
				A	.57	.53	.50	.50	.46	.44	.41	.40
SEMI-INDIRECT	12	 Distribution Upward - 60% Downward - 20%	 Prismatic glass; Cased glass bottom etched top; ENCLOSED TRANSLUCENT BOWLS	J	.16	.12	.09	.12	.09	.07	.06	.05
				I	.20	.16	.13	.16	.12	.10	.09	.07
				H	.24	.19	.16	.18	.14	.12	.11	.08
				G	.27	.23	.19	.21	.17	.14	.12	.10
				F	.30	.25	.21	.23	.19	.16	.14	.12
				E	.35	.30	.26	.27	.22	.20	.17	.14
				D	.38	.33	.29	.29	.25	.22	.19	.17
				C	.41	.36	.32	.31	.27	.24	.21	.19
				B	.46	.41	.37	.34	.31	.29	.23	.21
				A	.48	.44	.40	.37	.33	.31	.25	.23
SEMI-INDIRECT	13	 Distribution Upward - 70% Downward - 10%	 Dense glass bowl; Plastic; OPEN TOP TRANSLUCENT BOWLS	J	.17	.14	.12	.13	.10	.09	.07	.06
				I	.22	.18	.16	.16	.13	.12	.09	.08
				H	.25	.21	.19	.18	.15	.14	.11	.09
				G	.29	.25	.21	.21	.18	.16	.12	.11
				F	.31	.27	.24	.23	.20	.18	.13	.12
				E	.35	.31	.28	.26	.22	.20	.15	.14
				D	.39	.34	.31	.28	.25	.23	.17	.16
				C	.41	.37	.34	.30	.27	.25	.18	.17
				B	.45	.42	.39	.32	.30	.28	.20	.19
				A	.47	.44	.41	.34	.32	.30	.22	.20
INDIRECT	14	 Distribution Upward - 75% Downward - 0%	 Mirrored glass or Metal bowl - inside frosted lamp; Metal shield - silvered bowl lamp; M.F ,75; SHALLOW BOWL REFLECTORS AND SHIELDS	J	.15	.12	.10	.10	.08	.07	.04	.04
				I	.19	.15	.14	.13	.10	.09	.06	.05
				H	.22	.18	.16	.14	.12	.10	.08	.06
				G	.25	.21	.18	.17	.14	.13	.08	.08
				F	.27	.24	.21	.19	.16	.14	.09	.08
				E	.31	.27	.25	.21	.18	.16	.10	.10
				D	.34	.30	.28	.22	.20	.19	.12	.11
				C	.36	.33	.30	.24	.22	.20	.13	.12
				B	.40	.37	.34	.26	.25	.23	.14	.14
				A	.42	.39	.37	.28	.26	.25	.16	.14
INDIRECT	15	 Distribution Upward - 65% Downward - 0%	 DEEP METAL BOWLS AND TROUGHS	J	.13	.10	.09	.08	.07	.06	.04	.03
				I	.16	.13	.12	.11	.09	.08	.05	.05
				H	.19	.16	.14	.12	.10	.09	.06	.05
				G	.22	.19	.16	.15	.12	.11	.07	.06
				F	.24	.20	.18	.16	.14	.12	.08	.07
				E	.27	.24	.21	.18	.16	.14	.09	.08
				D	.30	.26	.24	.20	.18	.16	.10	.10
				C	.32	.29	.26	.21	.19	.18	.11	.10
				B	.35	.32	.30	.23	.21	.20	.12	.12
				A	.36	.34	.32	.25	.23	.21	.14	.12
INDIRECT	16	 Distribution Upward - 55% Downward - 0%	 WALL URN; COLUMN URN; WALL BOX	J	.11	.09	.07	.07	.06	.05	.03	.03
				I	.14	.11	.10	.09	.08	.07	.04	.04
				H	.16	.13	.12	.10	.09	.08	.06	.04
				G	.18	.16	.13	.13	.10	.09	.06	.06
				F	.20	.17	.15	.14	.12	.10	.07	.06
				E	.23	.20	.18	.15	.13	.12	.08	.07
				D	.25	.22	.20	.16	.15	.14	.09	.08
				C	.27	.24	.22	.18	.16	.15	.09	.09
				B	.29	.27	.25	.19	.18	.17	.10	.10
				A	.31	.29	.27	.21	.19	.18	.12	.10
INDIRECT	17	 Distribution Upward - 40% Downward - 0%	 RECESSED COVES; COFFERS	J	.08	.06	.05	.05	.04	.04	.02	.02
				I	.10	.08	.07	.07	.06	.05	.03	.03
				H	.12	.10	.09	.08	.06	.06	.04	.03
				G	.13	.11	.10	.09	.08	.07	.04	.04
				F	.15	.13	.11	.10	.08	.08	.05	.04
				E	.17	.15	.13	.11	.10	.09	.06	.05
				D	.18	.16	.15	.12	.11	.10	.06	.06
				C	.19	.18	.16	.13	.12	.11	.07	.06
				B	.21	.20	.18	.14	.13	.12	.08	.07
				A	.22	.21	.20	.15	.14	.13	.08	.08
INDIRECT	18	 Distribution Upward - 25% Downward - 0%	 CLOSE CEILING COVES	J	.05	.04	.03	.03	.03	.02	.02	.01
				I	.06	.05	.04	.04	.04	.03	.02	.02
				H	.07	.06	.05	.05	.04	.04	.02	.02
				G	.08	.07	.06	.06	.05	.04	.03	.02
				F	.09	.08	.07	.06	.05	.05	.03	.03
				E	.10	.09	.08	.07	.06	.06	.04	.03
				D	.11	.10	.09	.08	.07	.06	.04	.04
				C	.12	.11	.10	.08	.07	.07	.04	.04
				B	.13	.12	.12	.09	.08	.08	.05	.04
				A	.14	.13	.12	.10	.09	.08	.05	.05

Note: The Coefficients of Utilization are calculated for the specific light output and distribution characteristics shown at the left of the opposite page. Equipments illustrated are typical and are not intended to represent the specific performance of any manufacturer's product. The **Light output range** given below indicates variations to be expected between commercial equipments falling in any one of the several classifications, for which coefficients will be in proportion to the actual light output.

MAINTENANCE FACTOR Average Conditions	Factors Influencing the Selection of the Lighting Equipment
.70	**Light output range**—75 to 85%. **Source brightness**—moderately high but acceptable in low-wattage units, or where seeing requirements are more casual rather than fixed. **F.C. on Vertical**—fairly high. **Reflected glare**—moderately severe—comparable with units in Group 5. ¶ These units though highly efficient represent some compromise with certain quality factors; suitable for many store and commercial applications.
.75	**Light output range**—80 to 85% for the best quality diffusing glass; 65 or 70% for dense molded glass. **Source brightness**—moderate, controllable within limits by globe size or luminous area. **F.C. on Vertical**—fairly high. **Reflected glare**—fairly low. ¶ This group typifies many different contours of white glass enclosing globes. Elongated or stalactite globes give better illumination on vertical surfaces but with more glare and 10% lower coefficients of utilization.
.70	**Light output range**—75 to 85%—downward light 15 to 30%. **Source brightness**—usually satisfactory, should not exceed 500 foot-lamberts for office and school applications. **F.C. on Vertical**—somewhat less than semi-direct units. **Reflected glare**—inherently low. ¶ Enclosed units have the obvious advantage of slower depreciation and ease of maintenance.
.65	**Light output range**—70 to 80% (with desirable position of light source); downward light 5 to 15%. **Source brightness**—very low. Other quality characteristics very excellent, but open-bowl units should get a lower rating for depreciation than the enclosed units; the open units, however, are likely to be more satisfactory from the brightness standpoint.
.65	**Light output range**—70 to 80%. Indirect lighting inherently receives superior ranking from the standpoint of source brightness, reflected glare, shadows and other quality considerations. Wide angle distribution makes for a more uniform ceiling brightness but results in a slightly lower utilization in small rooms than units of equal output whose distribution is strongly upward.
.60	**Light output range**—60 to 70%. Inherent quality of indirect lighting. This group comprises many indirect units of current design and styling where output efficiency has been sacrificed to some extent to achieve pleasing reflector contour, smaller diameter, and decorative features.
.60	**Light output range**—50 to 60%; may vary considerably but well-designed equipments should attain average outputs of 55%. Limitations of space, the size and contour of special types of indirect reflectors generally sacrifice efficiency to achieve the balance and harmony called for in the general design plans. Reflector design must avoid spill light and high brightness on the walls or columns above the units.
.55	**Light output range**—35 to 45%. In small wall coves and ceiling coffers where lamps must be deeply recessed, or where the lip of the coves must be extended to a predetermined sight-line, the free opening is often relatively small and the cove output is correspondingly reduced. With good reflecting surfaces and favorable design, coves may fall in Group 16 from efficiency standpoint.
.55	This classification indicates a general zone of light output, assuming a 25% output downward from secondary reflecting surfaces. Usually custom built to fit individual architectural conditions, no general data are certain to apply to specific cases. While reflector output may be studied for its distribution to secondary reflecting surfaces, the actual utilization is likely to vary over a wide range. In large important projects, it may be necessary to build scale models to predetermine results.

TABLE No. 7—COMPUTED ILLUMINATION VALUES

$$\text{Lamp Lumens Required per Outlet} = \frac{\text{Footcandles} \times \text{Area in Square Feet per Outlet}}{\text{Coefficient of Utilization} \times \text{Maintenance Factor}}$$

Or, computing as below, for lamps of various sizes:

$$\text{Footcandles} = \frac{\text{Lamp Lumens} \times \text{Coef. of Util.} \times \text{Maintenance Factor}}{\text{Area in Sq. Ft. per Lamp}}$$

The calculations below are the result of arithmetical substitutions in the formula above, assuming a maintenance factor of .70. Values have been carried beyond the decimal for arithmetical checking only—rather than the degree of accuracy to expect in practice.

Area in Square Feet per Lamp	Size of Lamp		COEFFICIENT OF UTILIZATION																		
	Watts	Lumens	.14	.16	.18	.20	.22	.24	.26	.28	.30	.32	.34	.36	.40	.45	.50	.55	.60	.65	.70
			FOOTCANDLES																		
60	100	1500	2.5	2.8	3.1	3.5	3.8	4.2	4.5	4.9	5.3	5.6	5.9	6.3	7.0	7.9	8.8	9.6	10.5	11.4	12.3
	150	2500	4.1	4.7	5.3	5.8	6.3	7.0	7.6	8.2	8.8	9.3	10.0	10.5	11.7	13.1	14.6	16.0	17.5	19.0	20.4
	200	3400	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.1	11.9	12.7	13.5	14.3	15.9	17.8	19.8	21.8	23.8	25.8	27.8
	300	5500	9.0	10.3	11.6	12.8	14.1	15.4	16.7	18.0	19.3	20.5	21.8	23.1	25.7	28.9	32.1	35.3	38.5	41.7	45.0
	500	9800	16.0	18.3	20.3	22.9	25.2	27.5	29.7	32.0	34.3	36.6	38.9	41.2	45.8	51.5	57.2	62.9	68.6	74.4	80.0
70	100	1500	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	6.0	6.8	7.5	8.3	9.0	9.8	10.5
	150	2500	3.5	4.0	4.5	5.0	5.4	6.0	6.5	7.0	7.5	8.0	8.5	9.0	10.0	11.3	12.5	13.8	15 0	16.3	17.5
	200	3400	4.7	5.5	6.1	6.8	7.5	8.2	8.9	9.5	10.2	10.9	11.5	12.2	13.6	15.3	17.0	18.7	20.4	22.1	23.8
	300	5500	7.7	8.8	9.9	11.0	12.1	13.2	14.3	15.4	16.5	17.6	18.7	19.8	22.0	24.8	27.5	30.2	33.0	35.8	38.5
	500	9800	13.7	15.7	17.6	19.6	21.6	23.5	25.5	27.4	29.4	31.4	33.3	35.3	39.2	44.1	49.0	54.0	58.8	63.7	68.5
80	100	1500	1.8	2.1	2.4	2.6	2.9	3.1	3.4	3.7	3.9	4.1	4.4	4.6	5.2	5.9	6.6	7.2	7.9	8.5	9.2
	150	2500	3.1	3.5	3.9	4.4	4.8	5.3	5.7	6.1	6.6	7.0	7.4	7.9	8.8	9.8	10.9	12.0	13.1	14.2	15.3
	200	3400	4.2	4.8	5.4	5.9	6.5	7.1	7.7	8.3	8.9	9.5	10.1	10.7	11.9	13.4	14.9	16.4	17.9	19.3	20.8
	300	5500	6.7	7.7	8.7	9.6	10.6	11.5	12.5	13.5	14.5	15.4	16.4	17.3	19.3	21.6	24.1	26.5	28.9	31.3	33.7
	500	9800	12.0	13.7	15.5	17.2	18.9	20.5	22.3	24.0	25.7	27.5	29.1	30.9	34.4	38.6	43.0	47.2	51.5	55.8	60.0
90	100	1500	1.6	1.9	2.1	2.3	2.6	2.8	3.0	3.3	3.5	3.7	4.0	4.2	4.7	5.2	5.8	6.4	7.0	7.6	8.2
	150	2500	2.7	3.1	3.4	3.9	4.2	4.7	5.1	5.5	5.8	6.2	6.6	7.0	7.8	8.8	9.7	10.7	11.7	12.6	13.6
	200	3400	3.7	4.2	4.8	5.3	5.8	6.4	6.9	7.4	7.9	8.5	9.0	9.5	10.6	11.9	13.2	14.5	15.9	17.2	18.5
	300	5500	6.0	6.9	7.7	8.6	9.4	10.3	11.1	12.0	12.8	13.7	14.5	15.4	17.1	19.3	21.4	23.5	25.7	27.8	30.0
	500	9800	10.7	12.2	13.7	15.2	16.8	18.3	19.8	21.4	22.9	24.4	25.9	27.4	30.5	34.3	38.1	42.0	45.8	49.5	53.5
	750	14550	15.8	18.1	20.4	22.6	24.9	27.2	29.4	31.7	34.0	36.2	38.5	40.7	45.3	51.0	56.6	62.3	67.9	73.6	79.2
100	100	1500	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.4	3.6	3.8	4.2	4.6	5.3	5.8	6.3	6.8	7.4
	150	2500	2.5	2.8	3.2	3.5	3.8	4.2	4.6	4.9	5.3	5.6	6.0	6.3	7.0	7.9	8.8	9.6	10.5	11.4	12.3
	200	3400	3.3	3.8	4.3	4.8	5.2	5.7	6.2	6.7	7.1	7.6	8.1	8.6	9.5	10.7	11.9	13.1	14.3	15.5	16.7
	300	5500	5.4	6.2	6.9	7.7	8.5	9.2	10.0	10.8	11.5	12.3	13.1	13.9	15.4	17.3	19.3	21.2	23.1	25.0	27.0
	500	9800	9.6	11.0	12.3	13.7	15.1	16.5	17.7	19.2	20.6	21.9	23.3	24.7	27.4	30.9	34.3	37.7	41.2	44.6	48.0
	750	14550	14.3	16.3	18.3	20.4	22.4	24.5	26.5	28.6	30.6	32.6	34.7	36.7	40.8	45.9	51.0	56.1	61.2	66.3	71.4
110	100	1500	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.0	3.2	3.4	3.8	4.3	4.8	5.2	5.7	6.2	6.7
	150	2500	2.2	2.5	2.9	3.2	3.5	3.8	4.1	4.5	4.8	5.1	5.4	5.7	6.4	7.2	8.0	8.8	9.5	10.3	11.1
	200	3400	3.0	3.5	3.9	4.3	4.8	5.2	5.6	6.1	6.5	6.9	7.4	7.8	8.7	9.7	10.8	11.9	13.0	14.1	15.2
	300	5500	4.9	5.6	6.2	7.0	7.7	8.4	9.1	9.8	10.5	11.2	11.9	12.6	14.0	15.7	17.5	19.2	21.0	22.7	24.5
	500	9800	8.7	10.0	11.2	12.5	13.7	14.9	16.2	17.5	18.7	20.0	21.2	22.5	25.0	28.1	31.2	34.3	37.5	40.6	43.7
	750	14550	13.0	14.8	16.7	18.5	20.4	22.2	24.0	26.0	27.8	29.6	31.5	33.4	37.1	41.7	46.3	51.0	55.6	60.2	64.8
120	100	1500	1.2	1.4	1.6	1.8	1.9	2.1	2.3	2.5	2.6	2.8	3.0	3.1	3.5	3.9	4.4	4.8	5.2	5.7	6.1
	150	2500	2.0	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.4	4.7	5.0	5.3	5.8	6.6	7.3	8.0	8.8	9.5	10.2
	200	3400	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	5.9	6.4	6.7	7.2	8.0	9.0	10.0	11.0	12.0	13.0	14.0
	300	5500	4.5	5.1	5.8	6.4	7.1	7.7	8.4	9.0	9.6	10.3	10.9	11.5	12.8	14.4	16.0	17.6	19.2	20.8	22.4
	500	9800	8.0	9.1	10.3	11.4	12.6	13.7	14.9	16.0	17.2	18.3	19.4	20.6	22.9	25.7	28.6	31.4	34.3	37.2	40.0
	750	14550	11.9	13.6	15.3	17.0	18.7	20.4	22.1	23.8	25.5	27.2	28.9	30.6	34.0	38.2	42.5	46.7	51.0	55.2	59.4
130	150	2500	1.9	2.2	2.4	2.7	2.9	3.2	3.5	3.8	4.0	4.3	4.6	4.8	5.4	6.1	6.7	7.4	8.1	8.8	9.4
	200	3400	2.6	2.9	3.3	3.7	4.0	4.4	4.8	5.1	5.5	5.9	6.2	6.6	7.3	8.2	9.2	10.1	11.0	11.9	12.8
	300	5500	4.1	4.7	5.3	5.9	6.5	7.1	7.7	8.3	8.9	9.5	10.1	10.6	11.8	13.3	14.8	16.3	17.8	19.2	20.7
	500	9800	7.4	8.4	9.5	10.6	11.6	12.7	13.7	14.8	15.8	16.9	18.0	19.0	21.1	23.8	26.4	29.0	31.7	34.3	37.0
	750	14550	11.0	12.5	14.1	15.6	17.2	18.9	20.4	22.0	23.6	25.0	26.7	28.2	31.3	35.2	39.1	43.0	47.0	50.8	54.7
140	150	2500	1.8	2.0	2.3	2.5	2.7	3.0	3.3	3.5	3.8	4.0	4.3	4.5	5.0	5.6	6.3	6.9	7.5	8.1	8.8
	200	3400	2.4	2.7	3.1	3.4	3.7	4.1	4.4	4.8	5.1	5.4	5.8	6.1	6.8	7.6	8.5	9.3	10.2	11.0	11.9
	300	5500	3.8	4.4	5.0	5.5	6.0	6.6	7.1	7.7	8.2	8.8	9.3	9.9	11.0	12.4	13.7	15.1	16.5	17.9	19.3
	500	9800	6.9	7.8	8.8	9.8	10.8	11.8	12.8	13.7	14.7	15.7	16.7	17.6	19.6	22.1	24.5	27.0	29.4	31.8	34.3
	750	14550	10.2	11.7	13.1	14.6	16.0	17.5	18.9	20.4	21.8	23.3	24.8	26.2	29.1	32.8	36.4	40.0	43.7	47.3	51.0
150	150	2500	1.6	1.9	2.1	2.3	2.5	2.8	3.0	3.3	3.5	3.7	4.0	4.2	4.7	5.3	5.8	6.4	7.0	7.6	8.2
	200	3400	2.2	2.5	2.9	3.2	3.5	3.8	4.1	4.4	4.8	5.1	5.4	5.7	6.3	7.1	7.9	8.8	9.5	10.3	11.1
	300	5500	3.6	4.1	4.6	5.1	5.6	6.2	6.7	7.2	7.7	8.2	8.7	9.2	10.3	11.5	12.8	14.2	15.4	16.7	18.0
	500	9800	6.4	7.3	8.2	9.1	10.1	11.0	11.9	12.8	13.7	14.6	15.5	16.4	18.3	20.6	22.8	25.2	27.4	29.7	32.0
	750	14550	9.5	10.8	12.2	13.6	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	27.2	30.6	34.0	37.3	40.7	44.1	47.5
160	150	2500	1.5	1.8	2.0	2.2	2.4	2.6	2.8	3.1	3.3	3.5	3.7	3.9	4.4	4.9	5.5	6.0	6.6	7.1	7.7
	200	3400	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.9	6.7	7.4	8.2	8.9	9.7	10.4
	300	5500	3.4	3.9	4.3	4.8	5.3	5.8	6.3	6.7	7.2	7.7	8.2	8.7	9.6	10.8	12.0	13.2	14.4	15.6	16.8
	500	9800	6.0	6.9	7.7	8.6	9.4	10.3	11.2	12.0	12.9	13.7	14.6	15.4	17.2	19.3	21.4	23.6	25.7	27.9	30.0
	750	14550	8.9	10.2	11.4	12.7	14.0	15.3	16.6	17.8	19.1	20.4	21.7	22.9	25.4	28.6	31.8	35.0	38.2	41.4	44.5
	1000	20700	12.7	14.5	16.3	18.1	19.9	21.7	23.5	25.4	27.2	29.0	30.8	32.6	36.2	40.8	45.3	49.8	54.3	58.9	63.4
170	150	2500	1.4	1.6	1.9	2.1	2.2	2.5	2.7	2.9	3.1	3.3	3.5	3.7	4.1	4.6	5.1	5.7	6.2	6.7	7.2
	200	3400	2.0	2.2	2.5	2.8	3.1	3.4	3.6	3.9	4.2	4.5	4.8	5.0	5.6	6.3	7.0	7.7	8.4	9.1	9.8
	300	5500	3.2	3.6	4.1	4.5	5.0	5.4	5.9	6.4	6.8	7.2	7.7	8.2	9.1	10.2	11.3	12.5	13.6	14.7	15.9
	500	9800	5.7	6.5	7.3	8.1	8.9	9.7	10.5	11.3	12.1	12.9	13.7	14.5	16.2	18.2	20.2	22.2	24.2	26.2	28.3
	750	14550	8.4	9.6	10.8	12.0	13.2	14.4	15.6	16.8	18.0	19.2	20.3	21.6	24.0	27.0	30.0	33.0	36.0	39.0	42.0
	1000	20700	11.9	13.6	15.3	17.0	18.7	20.4	22.2	23.9	25.6	27.3	29.0	30.7	34.1	38.3	42.6	46.9	51.1	55.4	59.6

Lumen Output of Various Lamp Types and Sizes

The lumen outputs shown below apply only to lamps burned at rated voltage.

110-120-Volt Mazda Lamps

15 Watts.... 140 Lumens
25 Watts.... 260 Lumens
40 Watts.... 440 Lumens
60 Watts.... 760 Lumens
75 Watts.... 1065 Lumens
100 Watts.... 1530 Lumens
150 Watts.... 2535 Lumens
200 Watts.... 3400 Lumens
300 Watts.... 5520 Lumens
500 Watts /0150 9800 Lumens
750 Watts.... 14550 Lumens
1000 Watts.... 20700 Lumens
1500 Watts.... 33000 Lumens

220-240-Volt Mazda Lamps

25 Watts.... 215 Lumens
50 Watts.... 475 Lumens
100 Watts.... 1100 Lumens
200 Watts.... 2920 Lumens
300 Watts.... 4560 Lumens
500 Watts.... 8350 Lumens
750 Watts.... 13125 Lumens
1000 Watts.... 19000 Lumens

110-120-Volt Mazda Daylight

60 Watts ..... 495 Lumens
100 Watts ..... 990 Lumens
150 Watts ..... 1650 Lumens
200 Watts ..... 2210 Lumens
300 Watts ..... 3590 Lumens
500 Watts ..... 6370 Lumens

Mercury Lamps (Type H)

85 Watts.... 3000 Lumens
250 Watts.... 7500 Lumens
400 Watts.... 16000 Lumens

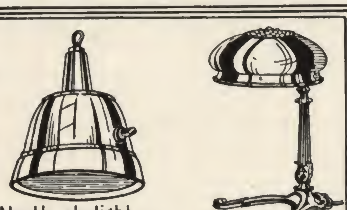
TABLE No. 7—COMPUTED ILLUMINATION VALUES (Continued)

Area in Square Feet per Lamp	Size of Lamp		COEFFICIENT OF UTILIZATION — FOOTCANDLES																		
	Watts	Lumens	.14	.16	.18	.20	.22	.24	.26	.28	.30	.32	.34	.36	.40	.45	.50	.55	.60	.65	.70
180	150	2500	1.4	1.5	1.8	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.9	4.4	4.9	5.3	5.8	6.3	6.8
	200	3400	1.9	2.1	2.4	2.6	2.9	3.2	3.4	3.7	4.0	4.2	4.5	4.8	5.3	6.0	6.6	7.3	7.9	8.6	9.3
	300	5500	3.0	3.4	3.9	4.3	4.7	5.1	5.6	6.0	6.4	6.8	7.3	7.7	8.6	9.6	10.7	11.8	12.8	13.9	15.0
	500	9800	5.3	6.1	6.9	7.6	8.4	9.1	9.9	10.7	11.4	12.2	12.9	13.8	15.3	17.2	19.1	21.0	22.8	24.8	26.7
	750	14550	7.9	9.1	10.2	11.3	12.4	13.6	14.7	15.8	17.0	18.1	19.2	20.4	22.6	25.4	28.3	31.1	34.0	36.8	39.6
	1000	20700	11.3	12.9	14.5	16.1	17.7	19.3	20.9	22.6	24.2	25.8	27.4	29.0	32.2	36.2	40.2	44.2	48.3	52.3	56.3
200	200	3400	1.7	1.9	2.1	2.4	2.6	2.9	3.1	3.3	3.6	3.8	4.0	4.3	4.8	5.4	6.0	6.6	7.2	7.7	8.3
	300	5500	2.7	3.1	3.5	3.8	4.2	4.6	5.0	5.4	5.8	6.2	6.5	6.9	7.7	8.7	9.6	10.6	11.6	12.5	13.5
	500	9800	4.8	5.5	6.2	6.9	7.6	8.2	8.9	9.6	10.3	11.0	11.7	12.4	13.7	15.5	17.2	18.9	20.6	22.3	24.0
	750	14550	7.1	8.1	9.2	10.2	11.2	12.2	13.2	14.3	15.3	16.3	17.3	18.3	20.4	22.9	25.4	28.0	30.6	33.1	35.6
	1000	20700	10.2	11.6	13.1	14.5	16.0	17.4	18.8	20.3	21.7	23.2	24.6	26.1	29.0	32.6	36.2	40.0	43.5	47.2	50.8
	1500	33000	16.2	18.5	20.8	23.2	25.4	27.7	30.0	32.4	34.6	37 0	39.2	41.6	46.3	52.0	57.8	63.6	69.4	75.2	81.0
220	200	3400	1.5	1.7	2.0	2.2	2.4	2.6	2.8	3.0	3.3	3.5	3.7	3.9	4.3	4.9	5.4	6.0	6.5	7.0	7.6
	300	5500	2.4	2.8	3.1	3.5	3.8	4.2	4.5	4.9	5.2	5.6	5.9	6.3	7.0	7.9	8.8	9.6	10.5	11.4	12.3
	500	9800	4.4	5.0	5.6	6.2	6.9	7.5	8.1	8.7	9.3	10.0	10.6	11.2	12.5	14.0	15.6	17.2	18.7	20.3	21.8
	750	14550	6.5	7.4	8.3	9.3	10.2	11.1	12.1	13.0	13.9	14.8	15.7	16.7	18.6	20.9	23.2	25.5	27.8	30.2	32.5
	1000	20700	9.2	10.5	11.9	13.2	14.5	15.8	17.1	18.5	19.7	21.1	22.4	23.7	26.4	29.6	33.0	36.2	39.5	42.8	46.1
	1500	33000	14.7	16.8	18.9	21.0	23.1	25.2	27.3	29.4	31.5	33.7	35.7	37.9	42.1	47.3	52.6	57.8	63.1	68.4	73.6
240	200	3400	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	4.0	4.5	5.0	5.5	5.9	6.4	6.9
	300	5500	2.2	2.6	2.9	3.2	3.5	3.8	4.2	4.5	4.8	5.1	5.4	5.8	6.4	7.2	8.0	8.8	9.6	10.4	11.2
	500	9800	4.0	4.6	5.2	5.7	6.3	6.9	7.4	8.0	8.6	9.2	9.7	10.3	11.4	12.9	14.3	15.8	17.2	18.6	20.0
	750	14550	5.9	6.8	7.6	8.5	9.3	10.1	11.0	11.9	12.7	13.6	14.4	15.3	17.0	19.0	21.2	23.3	25.5	27.5	29.7
	1000	20700	8.5	9.7	10.9	12.1	13.3	14.5	15.7	16.9	18.1	19.4	20.6	21.7	24.2	27.2	30.2	33.2	36.3	39.2	42.3
	1500	33000	13.5	15.4	17.4	19.3	21.2	23.1	25.0	27.0	28.9	30.8	32.7	34.7	38.6	43.4	48.2	53.0	57.8	62.6	67.5
260	200	3400	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.6	2.7	2.9	3.1	3.3	3.7	4.1	4.6	5.0	5.5	6.0	6.4
	300	5500	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.4	4.7	5.0	5.3	5.9	6.7	7.4	8.2	8.9	9.6	10.4
	500	9800	3.7	4.2	4.7	5.3	5.8	6.3	6.9	7.4	7.9	8.5	9.0	9.5	10.6	11.9	13.2	14.5	15.8	17.2	18.5
	750	14550	5.5	6.3	7.1	7.8	8.6	9.4	10.2	10.9	11.8	12.5	13.3	14.1	15.7	17.6	19.6	21.5	23.5	25.4	27.4
	1000	20700	7.8	8.9	10.0	11.2	12.3	13.4	14.5	15.6	16.7	17.9	19.0	20.1	22.3	25.1	27.9	30.7	33.5	36.3	39.1
	1500	33000	12.5	14.2	16.0	17.8	19.6	21.3	23.1	24.9	26.7	28.5	30.2	32.0	35.6	40.0	44.5	49.0	53.4	57.9	62.3
280	200	3400	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.8	3.0	3.1	3.5	3.9	4.4	4.8	5.1	5.7	6.0
	300	5500	1.9	2.2	2.5	2.8	3.0	3.3	3.6	3.9	4.1	4.4	4.7	5.0	5.5	6.2	6.9	7.6	8.3	8.9	9.6
	500	9800	3.4	3.9	4.4	4.9	5.4	5.9	6.4	6.9	7.3	7.9	8.3	8.8	9.8	11.0	12.3	13.5	14.7	15.9	17.2
	750	14550	5.1	5.8	6.5	7.3	8.0	8.7	9.5	10.2	10.9	11.6	12.3	13.1	14.6	16.4	18.2	20.0	21.8	23.7	25.5
	1000	20700	7.2	8.3	9.3	10.3	11.4	12.4	13.5	14.5	15.5	16.5	17.6	18.6	20.7	23.3	25.9	28.4	31.0	33.6	36.2
	1500	33000	11.6	13.2	14.9	16.5	18.2	19.8	21.4	23.1	24.7	26.4	28.0	29.8	33.0	37.2	41.3	45.5	49.5	53.7	57.8
320	200	3400	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.5	2.7	3.0	3.4	3.7	4.1	4.5	4.9	5.2
	300	5500	1.7	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.9	4.1	4.3	4.8	5.4	6.0	6.6	7.2	7.8	8.4
	500	9800	3.0	3.4	3.9	4.3	4.7	5.1	5.6	6.0	6.4	6.9	7.3	7.7	8.6	9.7	10.7	11.8	12.9	14.0	15.0
	750	14550	4.5	5.1	5.7	6.4	7.0	7.6	8.3	8.9	9.5	10.2	10.8	11.5	12.7	14.3	15.9	17.5	19.1	20.6	22.3
	1000	20700	6.3	7.3	8.2	9.1	10.0	10.9	11.8	12.7	13.6	14.5	15.4	16.3	18.1	20.4	22.6	25.0	27.2	29.4	31.7
	1500	33000	10.1	11.6	13.0	14.5	15.9	17.3	18.7	20.2	21.7	23.2	24.5	26.0	28.9	32.5	36.1	39.8	43.4	47.0	50.6
360	300	5500	1.5	1.7	1.9	2.1	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.3	4.8	5.3	5.9	6.4	7.0	7.5
	500	9800	2.7	3.0	3.4	3.8	4.2	4.6	4.9	5.3	5.7	6.1	6.5	6.9	7.6	8.6	9.5	10.5	11.4	12.4	13.4
	750	14550	4.0	4.5	5.1	5.7	6.2	6.8	7.4	7.9	8.5	9.1	9.6	10.2	11.3	12.8	14.2	15.6	17.0	18.4	19.8
	1000	20700	5.6	6.4	7.2	8.0	8.9	9.7	10.5	11.3	12.1	12.9	13.7	14.5	16.1	18.1	20.2	22.2	24.2	26.2	28.2
	1500	33000	9.0	10.3	11.6	12.8	14.1	15.4	16.7	18.0	19.3	20.6	21.8	23.1	25.7	28.9	32.1	35.3	38.6	41.8	45.0
400	300	5500	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.9	4.3	4.8	5.3	5.8	6.3	6.7
	500	9800	.4	2.7	3.1	3.4	3.8	4.1	4.5	4.8	5.1	5.5	5.8	6.2	6.9	7.7	8.6	9.4	10.3	11.2	12.0
	750	14550	3.6	4.1	4.6	5.1	5.6	6.1	6.6	7.1	7.6	8.2	8.7	9.2	10.2	11.5	12.7	14.0	15.3	16.5	17.8
	1000	20700	5.1	5.8	6.5	7.3	8.0	8.7	9.4	10.2	10.8	11.6	12.3	13.1	14.5	16.4	18.1	20.0	21.8	23.6	25.4
	1500	33000	8.1	9.3	10.4	11.6	12.7	13.9	15.0	16.2	17.3	18.5	19.7	20.8	23.2	26.0	28.9	31.8	34.7	37.6	40.5
450	300	5500	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.8	3.0	3.1	3.5	3.9	4.4	4.8	5.1	5.6	6.0
	500	9800	2.1	2.4	2.7	3.1	3.4	3.7	4.0	4.3	4.6	4.9	5.2	5.5	6.1	6.9	7.6	8.4	9.2	9.9	10.7
	750	14550	3.2	3.6	4.1	4.5	5.0	5.4	5.9	6.3	6.8	7.2	7.7	8.1	9.1	10.2	11.3	12.4	13.6	14.7	15.8
	1000	20700	4.5	5.2	5.8	6.5	7.1	7.7	8.4	9.0	9.7	10.3	10.9	11.6	12.9	14.5	16.1	17.7	19.4	21.0	22.6
	1500	33000	7.2	8.2	9.3	10.3	11.3	12.4	13.4	14.4	15.4	16.4	17.5	18.5	20.6	23.2	25.7	28.3	30.8	33.4	36.0
500	300	5500	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.6	2.8	3.1	3.5	3.8	4.2	4.6	5.0	5.4
	500	9800	1.9	2.2	2.5	2.7	3.0	3.3	3.6	3.8	4.1	4.4	4.7	4.9	5.5	6.2	6.9	7.6	8.2	8.9	9.6
	750	14550	2.8	3.3	3.7	4.1	4.5	4.9	5.3	5.7	6.1	6.5	6.9	7.3	8.1	9.2	10.2	11.2	12.2	13.3	14.3
	1000	20700	4.1	4.6	5.2	5.8	6.4	7.0	7.5	8.1	8.7	9.3	9.8	10.4	11.6	13.0	14.5	16.0	17.4	18.8	20.3
	1500	33000	6.5	7.4	8.3	9.2	10.2	11.1	12.0	12.9	13.9	14.8	15.7	16.6	18.5	20.8	23.1	25.5	27.7	30.0	32.4

Artificial Daylight, Color-Matching, and Color-Modifying Equipment

The duplication of natural daylight is confined largely to those industrial and commercial applications involving accurate color discrimination or color rendition in varying degree, depending upon the specific requirements. Even in this field difficulties arise because the colorist has been accustomed, perhaps through years of habit, to a specific daylight quality peculiar to his location. It is practical and expedient, however, to provide exact reproductions of daylight for any given requirement with the attendant advantage of constancy and 24-hour availability.

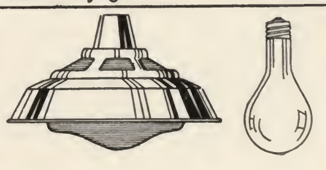
Although color quality is accurately specified by color temperature designations, equipments for reproducing daylight for working purposes may be grouped roughly into (1) skylight units, (2) sunlight units, and (3) units which provide a whiter light than the common types of general lighting equipment, but not so white as those discussed under A and B.


North skylight

A. Equipments of this character employ accurately correcting filters by means of which it is possible to duplicate the color of outdoor daylight. Generally designed for localized lighting over counters in stores, for small areas or special operations in industrial plants where precision in color identification, grading, and other color inspection is required. Illumination of the order of 100 footcandles is desirable for this sort of work.

Color factories, paint and dye mixing, art studios, chemical analysis, dental mechanics, surgery, textile and cigar sorting and grading are examples suggesting the application of skylight reproducing equipment.

As compared to unmodified artificial light, from 6 to 8 times the wattage is required for the same footcandle values.


Noon sunlight

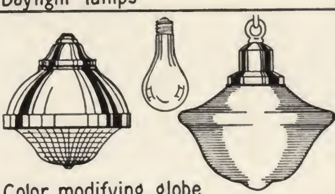
B. Enclosing globes of special crystal blue glass frosted on the inside modify the light from a lamp to approximate the color of direct sunlight at noon. Their applications are to some extent the same as skylight units, the actual choice depending on specific requirements; in general, noon sunlight equipment is used for less exacting color discrimination. For example, ink and dye mixing, and inspection may be done locally under skylight quality, and a general system of noon sunlight equipment may be installed in certain rooms or over small areas restricted to manufacturing operations requiring clear color rendition—such, for example, as lithographing processes, color printing, tobacco grading and the like. 100 or more footcandles generally recommended.

As compared to unmodified artificial light, from 2 to 3 times the wattage is required for the same footcandle values.


"Daylight" lamps

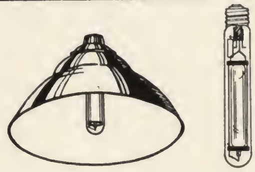
C. Lamps with blue bulbs, commercially known as MAZDA "Daylight" lamps, emit a whiter light which is but a partial step toward daylight whiteness. In many instances of color rendition, their use gives sufficient color correction to be of considerable advantage over the warmer tones of unmodified light. The light blends well with natural daylight; in fact in many cases it is about the same color as the daylight which one gets indoors taking into account the prevalence of warm tones in window shades, walls and hangings; for this reason the use of daylight lamps in offices and many other places will be found to correct an unsatisfactory mixture of ordinary artificial light and inadequate daylight.

The next larger size of lamp will be required to produce approximately the footcandle level as computed for a clear lamp of a given size. "Daylight" lamps can be used in all common types of equipment.

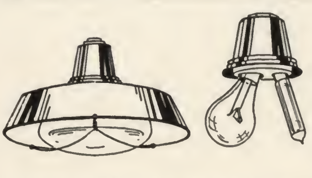

Color modifying globe

D. Enclosing globes with slight bluish ingredient do not appreciably modify the color quality of illumination for utilitarian purposes, but have a considerable field of application by virtue of their whiter appearance. Such equipment corrects the yellowish tone usually noticeable with ordinary opal glassware. These usually give far less color correction than MAZDA Daylight lamps. The units are very pleasing, appear white and clean, and are often more satisfactory than units of yellowish tone, particularly when supplementing natural daylight. The spectral quality of illumination is usually not far from that of a clear bulb MAZDA C lamp.

The illumination will be from 10% to 30% less than for the same type of unmodified globe.


Mercury lamps

E. The line spectrum of mercury vapor sources produces a characteristic color quality of light. It has a faint blue line, predominant yellow and green lines, with but a trace of red. The proportion of energy represented by each line varies slightly depending on the specific type of lamp. The source itself, or the light reflected from a white surface appears a bluish white but colored objects are much distorted in color appearance; blues become a purplish black, yellows and greens are emphasized, reds appear black. While colors cannot be reliably identified under mercury light, color contrast may be very pronounced. For that reason it may often be used as an auxiliary inspection source to reveal impurities and imperfections by introducing high color contrast that would not be apparent under white light.


Combination-Mercury-Incandescent

F. By combining mercury lamps lacking in red with incandescent lamps rich in red and orange, the resultant light is a very pleasing synthetic white light that seems cool and mixes well with natural daylight. There is still an excess of yellow and for that reason it is not a "color-discriminating" white because of the emphasis it gives yellow colors, but is very satisfactory for many industrial and commercial uses where accurate color discrimination of materials is not encountered. Combination low-pressure Cooper-Hewitt tubes and incandescent lamps offer a somewhat better color balance than combination of the new Type H vapor sources with incandescent lamps, but the latter combination is more efficient

In general, equal lumens from incandescent and from mercury lamps are recommended for most applications of combination units.

PART 3

SUPPLEMENTARY LIGHTING METHODS

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PART 3

SUPPLEMENTARY LIGHTING METHODS

Severe visual tasks of the work-world and modern merchandising methods require higher levels of illumination, to eliminate eyestrain or to highlight special displays, than are practical or economical to obtain from a system of general lighting alone. Supplementary lighting, as the name implies, should be employed in conjunction with a general lighting system, providing 10 to 20 footcandles. High levels of illumination for better seeing defeat their own purpose if glare, harsh shadows and severe contrasts between the brightly lighted area and surroundings are not eliminated.

The proper solution of supplementary lighting is not so much a question of computing the actual footcandles delivered as it is method employed, the equipment used, and its location with respect to the specific seeing task or the particular type of display. When these factors are determined, the lamp requirements may be computed from the distribution curve of the specific equipment or, as is often the case, may be determined experimentally.

The footcandles recommended for supplementary lighting can be roughly grouped into three general classifications according to the difficulty of the visual tasks involved. These classifications, referred to in Table 1, are as follows:

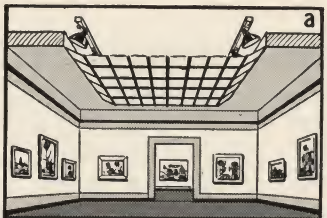
Class A—100 Footcandles or More. Necessary where visual tasks involve (1) Extremely fine detail, (2) Materials of exceptionally low or poor contrast, and (3) Prolonged duration.

Class B—50-100 Footcandles. Necessary where visual tasks involve (1) Fine detail, (2) Medium contrast in materials, and (3) Less prolonged duration.

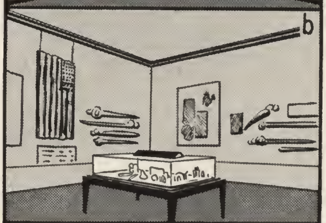
Class C—30-50 Footcandles. Necessary where visual tasks involve (1) Moderately fine detail, (2) Materials of average contrast, and (3) Critical seeing only intermittently.

Typical Supplementary or Specialized Lighting Equipment

SPECIAL APPLICATIONS



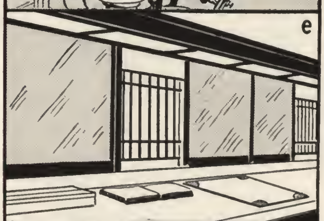
a—**Art Galleries.** A special solution is usually necessary for each installation. In general the hanging areas should be lighted in some such manner as illustrated, with concealed projectors behind stippled or ribbed glass sections. Illumination of the order of 50 footcandles will be provided by 300-watt Daylight lamps spaced 1½ to 2 feet apart. The supplementary lighting is usually coordinated with an artificial skylight which may furnish about 5 footcandles of general illumination.



b—**Museums—Special Exhibits.** Special study should be made of each exhibit and the lighting fitted to the specific conditions encountered. Many cases are suitably lighted with showcase equipment while others may require special color and natural shadow effects. Broad flat cases may be lighted by trough equipment as illustrated.

c—**Hospital—Operating Tables.** The best practice is to use a localized general system with concentrating reflectors or lens plates to concentrate the light on the operating zone from all directions in order to avoid harsh shadows. Two hundred or more footcandles should be provided. Adjustable spotlights will also be found useful when used with general illumination of 20 or more footcandles to relieve contrasts and shadows.

d—**Dental Chairs.** General illumination of at least 20 footcandles should be supplemented with two or three 150-watt lens units or louvered spotlights directed at the operating area.

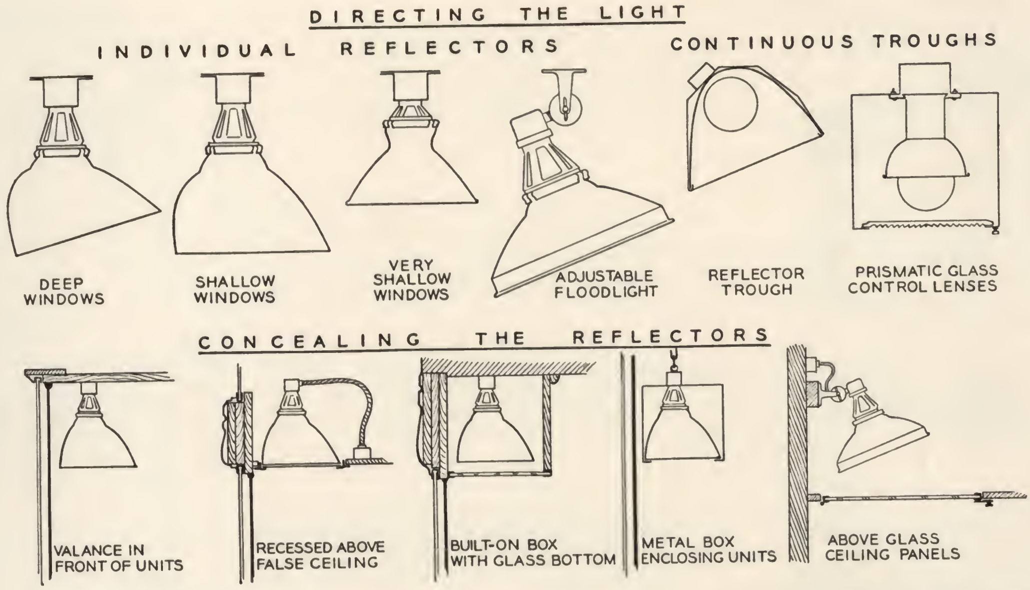


e—**Counters and Dealing Shelves.** In bank cages and ticket offices supplementary trough lighting equipment is usually located at the top of the cages to produce a band of light lengthwise of the counter. Troughs may be covered with diffusing glass or fitted with longitudinal louvers to shield the lamps. Sixty-watt lamps on 15 to 18-inch centers will generally be adequate.

f—**Business Machine Lighting.** Where power is brought to the desk for the operation of business machines and where the work is of a kind that is particularly difficult to see, bracket type units similar to the I.E.S. Reading lamp, permanently positioned on key punch machines, copy holders, and index references will, when equipped with 100-watt lamps, provide 60 footcandles of supplementary lighting on the work. For ordinary typing work, general lighting of 30 footcandles is recommended.

g—**Reading and Writing Rooms.** In hotels, libraries, waiting rooms and hospitals, supplementary lighting should be provided by means of portable reading lamps, in addition to the general illumination. Certified I.E.S. lamps in floor, table and wall type models are recommended from the standpoint of diffusion and distribution of light. On writing desks, the best location for portables is at the left-hand side of the desk.

SHOW WINDOWS AND DISPLAY CASES



Standard show window equipment should be chosen to fit window dimensions and to concentrate light on the trim line. Mirrored glass, polished metal, or prismatic units offer the control necessary to proper distribution. Reflectors should be concealed by valances or enclosed mounting. Louvers or stippled glass cover plates prevent glare where a row of units are exposed to the observer.

The better windows in brightly lighted districts use 300- and 500-watt units on 15 to 18-inch centers. At least 200-watts on 12-inch centers will be required for downtown city stores; 150-watt lamps for secondary business districts; 75- or 100-watt lamps for neighborhood stores and small towns.

Recommended footcandle standards serve principally as a relative gauge of requirement for different localities. Adjacent displays, traffic exposure, color, type and arrangement of merchandise and background are also prime factors in window effectiveness and emphasis.

Showcases and wall cases require from two to four times as many footcandles as the general illumination throughout the store if they are to stand out prominently and command attention. Standard showcase equipment is available for tubular bulb and Lumiline lamps and in individual mirrored reflectors taking the A bulb lamps.

A common shortcoming in the lighting of wall cases is the use of wide distribution reflectors which fail to concentrate the light on the merchandise display but produce predominant and oftentimes distracting light on the upper background. Small compact parabolic aluminum trough reflectors or other concentrating distribution units are best applied in most cases.

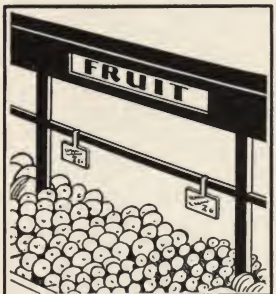
Large shallow cases may often best be lighted by a row of concentrating prismatic lens plates built in the top of the case.

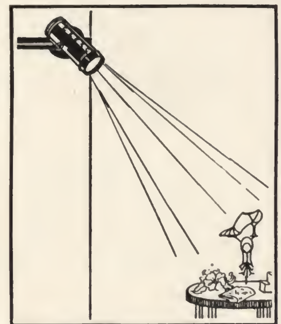
From 40 to 60 watts per running foot of showcase will be required to supply 50 to 100 footcandles along a normal curve of trim.

INTERIOR MERCHANDISE DISPLAY

Counter and Table Units

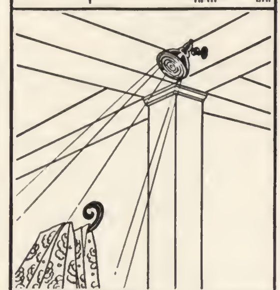
Spots and Floods





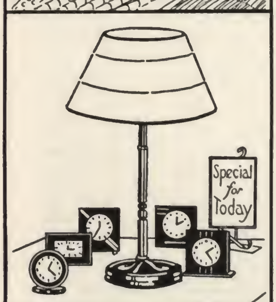
Continuous trough reflectors for counters, tables, island displays—mounted 3 feet above display with 40- to 60-watt lamps 10 to 15 inches apart should produce 50 to 100 footcandles on the merchandise. Translucent panels in the sides provide effective changeable advertising.

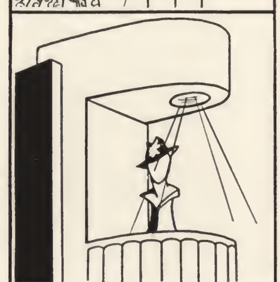
Small compact lens spots available in both 250- and 400-watt size mounted on columns, or ceiling brackets, give sales emphasis to small counter or table displays. Adjustable in spot size for 12- to 48-inch diameter spot at 10 feet. The 250-watt unit at 10 feet will deliver from 200 to 250 footcandles, with a 12- to 15-inch spot size; the 400-watt 350 to 450 footcandles.



Individual counter brackets about 2 feet above merchandise, spaced 3 feet apart and lamped with 60- to 100-watt lamps will provide 75 to 100 footcandles on the display. Daylight lamps used effectively for colored ornaments, costume jewelry and notions.

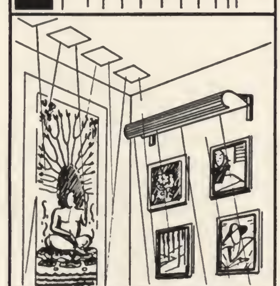
Louvered concentrating reflector spotlights available in 200- to 500-watt sizes give a less sharply defined beam than lens units. Spot size cannot be adjusted except by changing projection distances. A 200-watt unit at 10 feet will produce about 90 footcandles.





For small individual table displays, an I.E.S. table lamp with 100- or 150-watt lamp will provide 30 to 60 footcandles directly on the display contributing also to general lighting. Creates intimate, attractive display setting.

Lens plates or concentrating louvered reflectors may be built in a foot or two ahead of the vertical trim line, either in the soffit or floor of open display platforms or niches. 100- to 200-watt lamps will produce highlighting of 100 footcandles or more on the display.



Small metal bracket type reflectors with Lumiline or regular 25- or 40-watt tubular bulb lamps effectively emphasize small vertical display racks, stands and cabinets.

For extended vertical surface displays—rugs, tapestries, draperies, paintings—a series of 150- or 200-watt lens plate units at the ceiling is suitable for fixed display locations. Bracket-type parabolic, polished-metal troughs produce equivalent results and have some advantage in greater mobility.

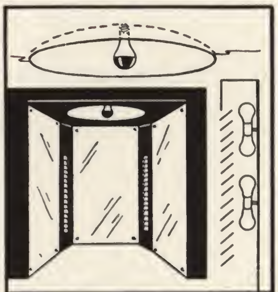
Counter units for accurate color matching of hose and shoes, thread and fabrics use blue glass absorbing filters to produce white light. A 300-watt unit with a 50% absorption plate (5000° K color temperature) should produce 200 footcandles at 18 inches. A second circuit with clear unmodified MAZDA lamps to produce approximately the same illumination should be provided for comparison purposes.

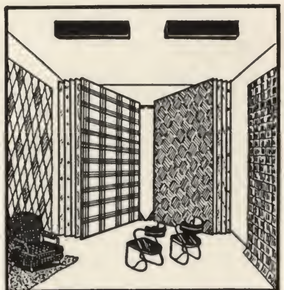
Footlight type trough lighting for counter and shelf displays ranges from single Lumiline reflectors for counter cards and small displays to extended shelf troughs as illustrated. Trough footlights with changeable, luminous sign panels transform waste space into valuable display.

INTERIOR MERCHANDISE DISPLAY

Mirrors and Fitting Rooms

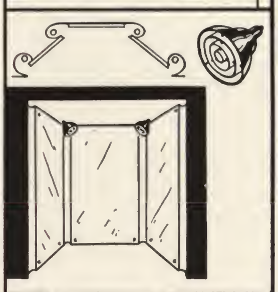
Shelving and Vertical Displays





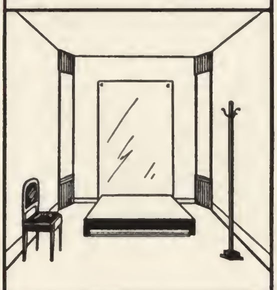
The problem in lighting mirror alcoves is to light the person and not the mirror. The sketch shows the use of a large aluminum ceiling reflector with a 500-watt silvered bowl lamp; also louvered vertical trough reflectors with 40-watt clear or 60-watt Daylight lamps on 6-inch centers.

Rug racks should be lighted as uniformly as possible from top to bottom. Concentrating units or parabolic trough reflectors with 150-watt lamps on 2-foot centers will provide 30 to 50 footcandles. Units should be aimed at the lower third of the rug.



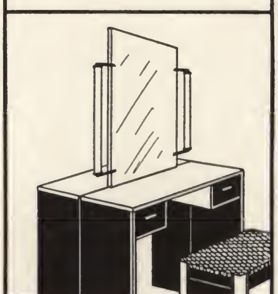
Louvered spotlights with 150-watt lamps, located at the upper intersections of the mirrors offer a simple means of supplementary lighting; shown also is a plan for vertical recessed luminous elements built in at the edges of the three sections of mirror, and using 60-watt Lumiline lamps.

For ready-to-wear displays it is desirable to secure fair uniformity both vertically and laterally and to provide from 50 to 100 footcandles. Illumination of this order is necessary to perceive and to identify coloring, tints and textures and is equivalent to the daylight near a window or door. A parabolic metal trough 8 to 12 inches out from the cases with 60- to 100-watt standard lamps spaced 12 inches is a very satisfactory method.



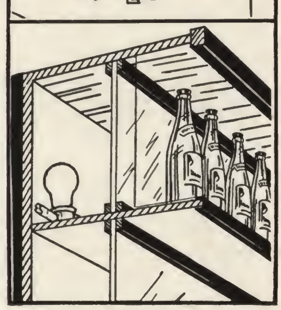
Fitting room mirrors entail the same requirements as other mirrors—the lighting emphasis may be obtained by louvered spots, built-in trough or lens plates, by luminous panels or louvered troughs. Where booths have white ceilings general illumination from indirect wall urns or indirect floor lamps will make the room more attractive.

For necessity and impulse items such as groceries, where attention rather than critical seeing is the requirement, less engineering refinement is needed in shelf lighting equipment. Concentrating trough reflectors which incorporate luminous panels for changeable advertising copy are satisfactory. Sockets a foot apart may be lamped with 40 to 100 watts as conditions dictate.



Small vanity table mirrors, require only a 60-watt white Lumiline lamp in a portable reflector holder on each side of the mirror for acceptable lighting for millinery fitting. Larger vanity and dresser mirrors may have large built-in vertical panels.

For lighting displays on columns or built-in shelving a metal nosing along the front edge of each shelf effectively conceals small 25-watt tubular lamps as shown in the sketch. Lamps should be spaced not more than 12 inches apart. Lumiline lamps are of course equally suitable in many cases.



Beauty parlor booths present various lighting problems depending on the construction of the booth and the seeing task involved. The sketch shows a large area aluminum reflector with a 200- or 300-watt silvered bowl lamp, adaptable as a low brightness source to individual open top booths.

Displays of glassware and bottled goods are highly attractive and colorful if lighted by transmitted light as shown. An opal glass panel, illuminated uniformly from behind with lamps spaced not more than 1½ times their distance back of the glass will provide a suitable luminous background.

INDUSTRIAL APPLICATIONS

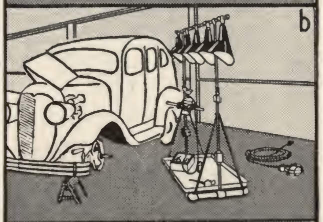
— a —

Vertical Surfaces, Craneways, Wash Racks

Angle Reflectors

Often used in craneways and erecting shops, mounted below the crane rail, preferably 20 feet above floor, to supplement general overhead lighting and to build up the lighting on vertical surfaces. Used also to light individual machines, auto wash racks, and other operations that demand special distribution or direction of light. Special care is necessary in locating and shielding units to avoid their becoming glare sources to workers who face toward the units.

For fairly uniform lighting laterally along a vertical surface, such as a posterboard, the spacing between units should not exceed 1½ times their distance out from the lighted surface.

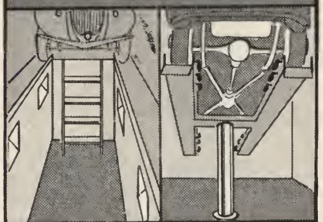


— b —

Garages, Hangars

Portable Garage and Repair Standards

For automotive repair work and critical inspection of parts. The usual extension cord equipped with 50- or 100-watt Rough Service Mazda lamps in a guard is indispensable for quick inspection and minor adjustments. Time-saver lighting in the form of two or more angle reflectors mounted on a heavy base or a portable rack is illustrated with outlets for electrical tools. The lighting units can be kept clean and efficient, harsh shadows are avoided, glare is eliminated and the worker is free of the nuisance of interference and continual shifting of the unit to avoid shadows. 200-watt units are recommended.



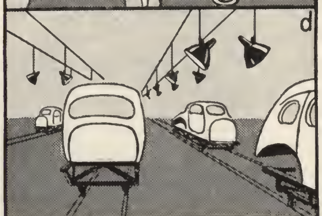
— c —

Garages, Roundhouses, Service Stations

Repair Pit and Auto Lift Lighting

The problem of lighting dark colored undersurfaces of trucks, chassis, and body, necessitates small equipments in sufficient number not only to give coverage but also to reduce shadows to a reasonable degree. Recessed angle reflectors with lens type cover plates or special heavy-duty pit lighting equipment with prismatic covers and wire guards are used for automotive, trolley, and roundhouse repair pits. Units on 6- to 8-foot spacing on each side of the pit with 100- to 200-watt lamps recommended.

On auto lifts 6 units on each side of the wheel track with 50- or 100-watt Rough Service lamps in wire guards and upturned half-shade reflectors are quite satisfactory.

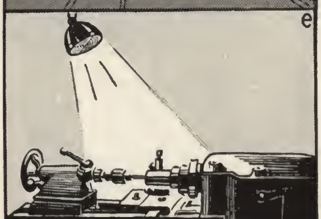


— d —

Auto Assembly, Body Finishing, Spray Booths

Special Purpose Projectors

Enclosed industrial projectors employing mercury or incandescent lamps find many applications in specialized lighting for many seeing tasks encountered in industry. The application illustrated shows the use of projector units with fluted cover glasses to spread a high level band of light on the vertical surfaces of an auto body for finishing and inspecting. With 300-watt units, equipped with spread lens and spaced 5 feet apart, the illumination on the working surface is of the order of 100 footcandles. A single 200-watt unit, without a spread lens will provide about 200 footcandles over an area of 7 to 8 square feet at a distance of 5 feet.

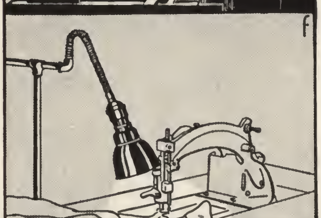


— e —

Machine Lighting, Printing, Proofreading, Cloth Products, Woodworking

Louvered Industrial Spotlights

To provide high level lighting over restricted areas where critical seeing demands from 50 to 250 footcandles—encountered in thousands of applications in the machine tool, woodworking, printing and mechanical industries. Such units out of the way of the workmen will provide glare-free lighting but particular care must be exercised in their location so that confusing shadows are not introduced. A 150-watt unit will provide about 175 footcandles at a 5-foot distance.



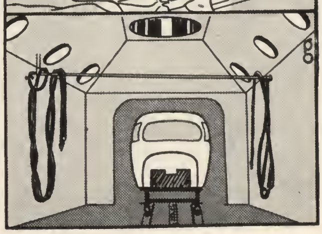
— f —

Machine Lighting, Sewing, Cloth Products, Glove Mfg., Hat Mfg., Leather Mfg., Shoe Mfg.

Adjustable Local Lighting

Deep bowl porcelain enameled or aluminum reflectors, with substantial supports, holders and adjustment features, are suitable for intimate individualized purposes such as sewing machines, linotype, etc. Half-shade reflectors even though adjusted to the satisfaction of the operators are likely to be glaring to others.

25- to 60-watt inside-frosted lamps will provide 50 to 150 footcandles at a distance of 6 inches. For many purposes, such as sewing, Daylight lamps are being used because of the whiter quality of light.



— g —

Paintshops, Refineries, Flour Mills

Vapor-Proof and Explosion-Proof Equipments

Designed for locations where corrosive vapor, inflammable gases or explosive dusts are likely to be encountered. In moisture-laden atmospheres such as steam processing, engine rooms, shower baths, also where gases and vapors from such processes as oil refining, paint and varnish making, spray lacquer painting, units of this character are recommended. Mandatory requirements are covered in detail in the National Electrical Code.

The sketch shows the application of vapor-proof equipment in a spray paint booth. Equipments include both angle and symmetrical types of reflectors in the range from 75- to 500-watt sizes.

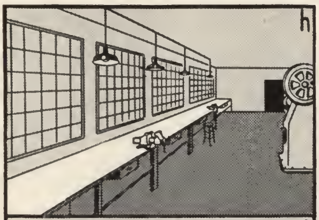
INDUSTRIAL APPLICATIONS

Bench and Inspection Lighting

General lighting alone will not usually be adequate for bench work requiring critical detailed seeing necessary in fine processing, assembly, or inspection. RLM Dome or Deep Bowl porcelain enameled reflectors can be spaced 1½ times the mounting height above the bench. At a 3-foot mounting, 150-watt inside-frosted lamps will produce 60 footcandles; 200-watt, 90 footcandles. RLM domes with white bowl lamps, Glassteel Diffusers, or trough sections (see i, j, k) with diffusing glass cover plate are recommended where seeing task requires avoidance of specular reflection and harsh shadows. Parabolic, louvered concentrating single units or continuous parabolic trough sections with silvered bowl lamps are recommended particularly at higher mounting heights, in order to produce a uniform, high level band of illumination along the bench. From 50 to 100 or more footcandles required, depending on the fineness of the task.

— h —

Bench Work, Assembly, Inspection

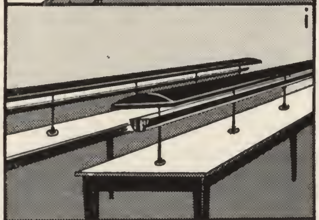


Assembly and Inspection Table Lighting

In many industrial operations, work positions are fixed and materials flow on belts or conveyors in front of operators for processing, labeling, assembly or inspection. In many instances, continuous diffusing or concentrating sources of illumination offer a good solution, though each job requires analysis and modification to meet specific requirements. With the light source at eye level or below, direct glare is eliminated. Where the material or operation does not introduce glaring reflections, open-type, continuous troughs are satisfactory; where shiny or polished material is present, diffusing reflector or diffusing glass cover panel should be used. In some instances duplicate facilities must be provided, (1) diffuse lighting for certain defects, and (2) directional lighting or glint which may be essential to reveal others.

— i —

Specialized Assembly, Inspection

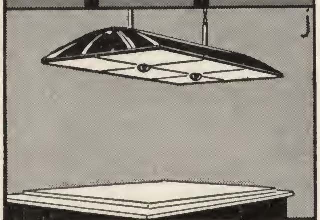


Large Area Diffusing Sources

Large area sources of low surface brightness and good diffusion are necessary for assembly and inspection where the work surfaces or parts of it are shiny, such as the fresh cast type on the printer's imposing stone illustrated. Large diffusing sources minimize obscuring reflections, and the illumination on the work may be built up to high values without uncomfortable brightness. A painted metal or matte porcelain reflecting housing using neck frosted silvered bowl lamps and a frosted cover glass may be used. Similar construction is likewise satisfactory in many instances when used in a vertical position to simulate direction and quality of normal window lighting.

— j —

Engraving, Printing, Lithographing, Jewelry and Watch Mfg., Sheet Metal Inspection



Diffusing Trough Units

Small trough units of porcelain enamel with diffusing cover glass find much application in lighting extended surfaces such as on shearing and cutting machines, carpet looms, and printing presses where a uniform band of light is required. Space limitations often dictate the design of the unit and type of lamp used; standard units are listed in equipment catalogs.

Open or louvered troughs may be used where the materials lighted are in themselves diffusing, but where specular materials or machine parts are encountered the light should be diffused at the source.

— k —

Fine Assembly, Inspection, Grinding, Polishing, Glass Inspection

Directional Light

Surface flaws, irregularities in surface shape, pit marks, scratches and cracks in materials are most easily seen by lighting which strikes the surface obliquely, casting a shadow and revealing the irregularities by shadow contrast. Thus unevenness in the nap of carpet or cloth is revealed by small shadows emphasized by a sharp directional light. The light may be undiffused for diffusing materials but diffused at the source for polished or shiny materials; thus ball bearings, pistons, valve stems and similar objects may be examined for flaws by viewing them on a luminous glass panel.

— l —

Inspection

Transmitted Light

Open weave fabrics, porous and translucent materials, such as glass, paper plastics, and liquids will reveal certain kinds of faults and defects by transmitted light. Large luminous panels of diffusing glass may be built in conveyor lines over which the material flows, or luminous vertical panels may be used as artificial windows against which such materials may be viewed.

— m —

Inspection

Refraction

Refractive materials such as plate glass, bottles, bulbs, etc., when viewed against a luminous background will reveal bubbles, blisters, cracks, chips and whorls by highlights or distortions. Alternating the observation between dark and luminous backgrounds introduces movement which aids in locating and identifying defect.

Similarly, surface distortions and irregularities in polished sheet metal or window glass are revealed by the distortion of reflected images of straight lined bars or strips laid on the luminous background.

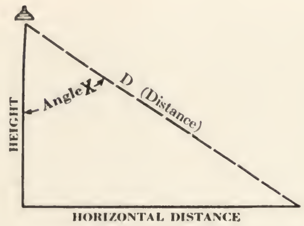
— n —

Inspection

LIGHTING CALCULATIONS

Point-by-Point Tables

In employing specialized equipment to produce a specific type of distribution of light, the distribution curve of the particular reflector under consideration must be studied from the standpoint of its efficiency and control of light, and the candlepower distribution at various angles. Only from such a curve or data is it possible to compute footcandles at a given point from one or more units.

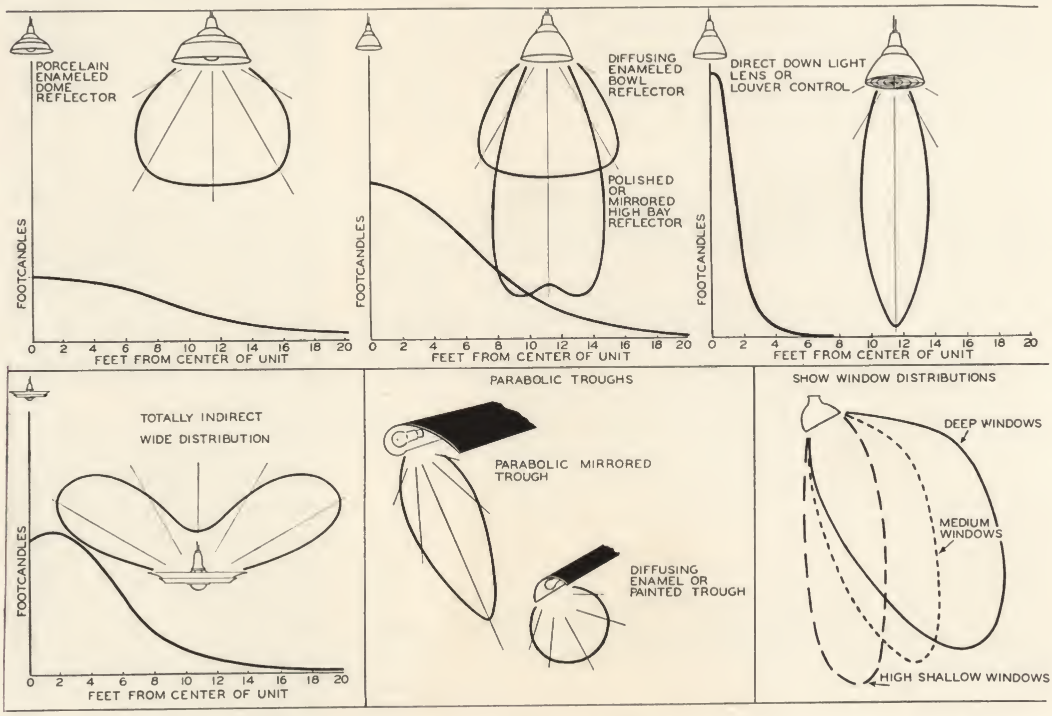


The point-by-point method of lighting calculation is based on the "inverse square law"; that is, that the intensity of light varies inversely as the square of the distance from the light source to the point of measurement. From a candlepower distribution curve of a reflector, the footcandles at any given point may be computed from the formula—

(1) $\text{Footcandles} = \dfrac{\text{CP (Candlepower)}}{\text{D}^2 \text{ (Distance in feet)}}$
(Normal to the beam)

(2) $\text{Footcandles} = \dfrac{\text{CP}}{\text{D}^2} \times \text{Cosine of Angle X}$
(On horizontal plane)

In Table 8 the footcandles on the horizontal plane have been calculated from Formula 2 for a source of 100 candlepower for a wide range of mounting heights and distances out from the reflector. For the higher mounting height or projection distances encountered in powerful projectors the values have been computed per 100,000 candlepower to avoid the confusion of many decimal places. Given also is the angle in degrees so that at any given height and distance out, the actual candlepower for that particular angle may be taken directly from the distribution curve of the unit. By multiplying the delivered candlepower (in hundreds or fractions of hundreds) at this angle by the footcandles produced per hundred candlepower as given in the table, the resultant horizontal footcandles at the point may be obtained.



Typical distribution curves which demonstrate that desired control and distribution of light are functions not only of reflector contour but also of the character of reflecting surfaces. For example, the enameled dome and deep bowl are widely different in contour but produce about the same distribution of light, whereas the porcelain enameled deep bowl and the polished or mirrored high bay reflector are quite similar in physical contour but produce markedly different distributions of light. Appraisal of specific lighting equipment and its proper application should proceed from specific performance data or from experienced judgment of light control principles.

TABLE No. 8

Upper Figures—Angle Between Light Ray and Vertical
Lower Figures—Footcandles on a Horizontal Plane Produced by a Source of 100 Candlepower

HORIZONTAL DISTANCE FROM UNIT—FEET

HEIGHT OF LIGHT SOURCE ABOVE SURFACE TO BE LIGHTED—FEET	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4	0° 0′ 6.250	14° 5.707	27° 4.472	37° 3.200	45° 2.210	51° 1.524	56° 1.066	60° .764	63° .559	66° .419	68° .320	70° .249	72° .198	73° .159	74° .130	75° .107
5	0° 0′ 4.000	11° 3.771	22° 3.202	31° 2.522	39° 1.904	45° 1.414	50° 1.050	54° .785	58° .595	61° .458	63° .358	66° .283	67° .228	69° .185	70° .152	72° .126
6	0° 0′ 2.778	9° 2.673	18° 2.372	27° 1.987	34° 1.600	40° 1.260	45° .982	49° .766	53° .600	56° .474	59° .378	61° .305	63° .249	66° .205	67° .170	68° .142
7	0° 0′ 2.041	8° 1.980	16° 1.814	23° 1.585	30° 1.336	36° 1.100	41° .893	45° .722	49° .583	52° .473	55° .385	58° .316	60° .261	62° .218	63° .183	65° .154
8	0° 0′ 1.563	7° 1.527	14° 1.427	21° 1.283	27° 1.118	32° 953	37° .800	41° .640	45° .552	48° .458	51° .381	54° .318	56° .267	58° .225	60° .191	62° .163
9	0° 0′ 1.235	6° 1.212	13° 1.148	18° 1.054	24° .943	29° .825	34° .711	38° .607	42° .515	45° .437	48° .370	51° .314	53° .267	55° .228	57° .196	59° .168
10	0° 0′ 1.000	5° 43′ .985	11° .943	17° .879	22° .801	27° .716	31° .631	35° .550	39° .476	42° .411	45° .354	48° .305	50° .263	52° .227	54° .196	56° .171
11	0° 0′ .826	5° 12′ .816	10° .787	15° .742	20° .686	24° .623	29° .559	32° .496	36° .437	39° .383	42° .335	45° .292	48° .255	50° .223	52° .195	54° .171
12	0° 0′ .694	4° 46′ .687	9° .668	14° .634	18° .593	23° .546	27° .497	30° .448	34° .400	37° .356	40° .315	43° .278	45° .246	47° .217	49° .191	51° .169
13	0° 0′ .592	4° 24′ .587	9° .571	13° .547	17° .517	21° .481	25° .447	28° .404	32° .366	35° .329	38° .295	40° .263	43° .235	45° .200	47° .187	49° .166
14	0° 0′ .510	4° 5′ .506	8° .495	12° .477	16° .454	20° .426	23° .396	27° .365	30° .334	33° .304	36° .275	38° .248	41° .223	43° .201	45° .180	47° .162
15	0° 0′ .444	3° 49′ .442	8° .433	11° .419	15° .401	18° .380	22° .356	25° .331	28° .305	31° .280	34° .256	36° .233	39° .212	41° .192	43° .174	45° .157
16	0° 0′ .391	3° 35′ .388	7° .382	11° .371	14° .357	17° .339	21° .321	24° .300	27° .280	29° .259	32° .238	35° .219	37° .200	39° .183	41° .167	43° .152
17	0° 0′ .346	3° 22′ .344	7° .339	10° .331	13° .319	16° .306	19° .290	22° .274	25° .256	28° .239	30° .222	33° .205	35° .189	37° .174	39° .159	41° .146
18	0° 0′ .309	3° 11′ .307	6° .303	9° .297	13° .287	16° .276	18° .264	21° .250	24° .236	27° .221	29° .206	31° .192	34° .178	36° .165	38° .152	40° .140
19	0° 0′ .277	3° 1′ .276	6° .273	9° .267	12° .260	15° .251	18° .240	20° .229	23° .217	25° .205	28° .192	30° .180	32° .167	34° .156	36° .145	38° .134
20	0° 0′ .250	2° 51′ .249	5° 43′ .246	9° .242	11° .236	14° .228	17° .219	19° .210	22° .200	24° .190	27° .179	29° .163	31° .158	33° .147	35° .137	37° .128
21	0° 0′ .227	2° 44′ .226	5° 26′ .224	8° .220	11° .215	13° .210	16° .201	18° .194	21° .185	23° .176	25° .167	28° .158	30° .144	32° .139	34° .131	36° .122
22	0° 0′ .207	2° 36′ .206	5° 10′ .205	8° .201	10° .196	13° .192	15° .185	18° .179	20° .171	22° .164	25° .155	27° .148	29° .140	31° .132	33° .124	34° .114
23	0° 0′ .189	2° 29′ .189	4° 58′ .187	7° .184	10° .181	12° .176	15° .171	17° .165	19° .159	21° .153	24° .146	26° .139	28° .132	29° .125	31° .118	33° .111
24	0° 0′ .174	2° 23′ .173	4° 45′ .172	7° .170	10° .166	12° .163	14° .158	16° .154	18° .148	21° .143	23° .137	25° .130	27° .124	28° .118	30° .112	32° .106
25	0° 0′ .160	2° 17′ .160	4° 34′ .158	7° .157	9° .154	11° .151	14° .147	16° .143	18° .138	20° .133	22° .128	24° .123	26° .117	27° .112	29° .106	31° .101
27	0° 0′ .137	2° 7′ .137	4° 14′ .136	6° .135	8° .133	10° .130	12° .128	15° .124	17° .121	18° .117	20° .113	22° .109	24° .105	26° .100	27° .096	29° .092
30	0° 0′ .111	1° 54′ .111	3° 50′ .111	5° 43′ .109	8° .108	9° .107	11° .105	13° .103	15° .100	17° .098	18° .095	20° .092	22° .089	23° .086	25° .083	27° .080
33	0° 0′ .092	1° 44′ .092	3° 28′ .091	5° 12′ .091	7° .090	9° .089	10° .087	12° .086	14° .084	15° .082	17° .080	18° .078	20° .076	22° .074	23° .072	24° .069
36	0° 0′ .077	1° 36′ .077	3° 11′ .077	4° 46′ .076	6° .076	8° .075	9° .074	11° .073	13° .072	14° .070	16° .069	17° .067	18° .066	20° .064	21° .062	23° .061
40	0° 0′ .063	1° 26′ .062	2° 52′ .062	4° 17′ .062	5° 43′ .062	7° .061	9° .060	10° .060	11° .059	13° .058	14° .057	15° .056	17° .055	18° .054	19° .053	21° .051
45	0° 0′ .049	1° 16′ .049	2° 33′ .049	3° 49′ .049	5° 5′ .049	6° .049	8° .048	9° .048	10° .047	11° .047	13° .046	14° .045	15° .045	16° .044	17° .043	18° .042
50	0° 0′ .040	1° 9′ .040	2° 17′ .040	3° 26′ .040	4° 34′ .040	5° 43′ .039	7° .039	8° .039	9° .039	10° .038	11° .038	12° .037	14° .037	15° .036	16° .036	16° .035
55	0° 0′ .033	1° 2′ .033	2° 5′ .033	3° 7′ .033	4° 10′ .033	5° 9′ .033	6° .032	7° .032	8° .032	9° .032	10° .032	11° .031	12° .031	13° .031	14° .030	15° .030
60	0° 0′ .028	0° 57′ .028	1° 55′ .028	2° 52′ .028	3° 50′ .028	4° 46′ .027	5° 43′ .027	7° .027	8° .027	9° .027	9° .027	10° .026	11° .026	12° .026	13° .026	14° .025
70	0° 0′ .020	0° 49′ .020	1° 38′ .020	2° 34′ .020	3° 16′ .020	4° 5′ .020	4° 54′ .020	5° 43′ .020	7° .020	7° .020	8° .020	9° .020	10° .020	11° .019	11° .019	12° .019
100.000 CANDLEPOWER SOURCE																
80	0° 0′ 15.625	0° 43′ 15.616	1° 26′ 15.610	2° 9′ 15.592	2° 52′ 15.567	3° 35′ 15.534	4° 17′ 15.494	5° 0′ 15.447	5° 43′ 15.393	6° 15.345	7° 15.270	8° 15.186	9° 15.093	9° 15.036	10° 14.930	11° 14.817
100	0° 0′ 10.000	0° 34′ 9.999	1° 9′ 9.994	1° 43′ 9.987	2° 17′ 9.976	2° 52′ 9.963	3° 26′ 9.946	4° 0′ 9.927	4° 34′ 9.905	5° 9′ 9.880	5° 43′ 9.852	6° 9.826	7° 9.785	7° 9.761	8° 9.712	9° 9.660
125	0° 0′ 6.400	0° 28′ 6.399	0° 55′ 6.398	1° 22′ 6.395	1° 50′ 6.390	2° 17′ 6.385	2° 45′ 6.378	3° 12′ 6.370	3° 40′ 6.361	4° 7′ 6.351	4° 34′ 6.339	5° 2′ 6.326	5° 29′ 6.313	6° 6.297	6° 6.286	7° 6.262
150	0° 0′ 4.444	0° 23′ 4.444	0° 46′ 4.443	1° 9′ 4.442	1° 32′ 4.440	1° 55′ 4.437	2° 17′ 4.434	2° 40′ 4.430	3° 2′ 4.421	3° 26′ 4.416	3° 49′ 4.415	4° 11′ 4.409	4° 34′ 4.402	4° 57′ 4.395	5° 20′ 4.387	5° 43′ 4.379
175	0° 0′ 3.265	0° 20′ 3.265	0° 39′ 3.265	0° 59′ 3.264	1° 19′ 3.263	1° 38′ 3.261	1° 58′ 3.260	2° 17′ 3.258	2° 37′ 3.255	2° 57′ 3.252	3° 16′ 3.249	3° 36′ 3.246	3° 55′ 3.242	4° 15′ 3.238	4° 34′ 3.234	4° 54′ 3.230
200	0° 0′ 2.500	0° 17′ 2.500	0° 34′ 2.500	0° 52′ 2.499	1° 9′ 2.499	1° 26′ 2.498	1° 43′ 2.497	2° 0′ 2.495	2° 17′ 2.494	2° 35′ 2.492	2° 52′ 2.490	3° 9′ 2.489	3° 26′ 2.487	3° 43′ 2.484	4° 0′ 2.482	4° 17′ 2.479

TABLE No. 8

Upper Figures—Angle Between Light Ray and Vertical
Lower Figures—Footcandles on a Horizontal Plane Produced by a Source of 100 Candlepower

HEIGHT OF LIGHT SOURCE ABOVE SURFACE TO BE LIGHTED—FEET	HORIZONTAL DISTANCE FROM UNIT—FEET																
	16	17	18	19	20	22	24	26	28	30	32	34	36	40	44	48	52
4	76° .090	77° .075	78° .064	78° .055	79° .047	80° .037	81° .028	81° .022	82° .018	82° .015	83° .012	83° .010	84° .008	84° .006	85° .005	85° .004	86° .003
5	73° .106	74° .090	74° .077	75° .066	76° .057	77° .044	78° .034	79° .027	80° .022	81° .017	81° .015	82° .012	82° .010	83° .008	84° .006	84° .005	85° .004
6	69° .120	71° .102	71° .088	72° .076	73° .066	75° .051	76° .040	77° .032	78° .026	79° .021	79° .017	80° .015	80° .012	81° .009	82° .007	83° .005	83° .004
7	66° .131	68° .113	69° .097	70° .084	71° .074	72° .057	74° .045	75° .036	76° .029	77° .024	78° .020	78° .017	79° .014	80° .010	81° .008	82° .006	82° .005
8	63° .140	65° .121	66° .105	67° .091	68° .080	70° .063	72° .050	73° .040	74° .032	75° .026	76° .022	77° .019	77° .016	79° .012	80° .009	81° .007	81° .006
9	61° .146	62° .126	63° .110	65° .097	66° .085	68° .067	69° .053	71° .043	72° .035	73° .029	74° .025	75° .021	76° .018	77° .013	78° .010	79° .008	80° .006
10	58° .149	60° .130	61° .115	62° .101	63° .089	66° .071	67° .057	69° .046	70° .038	72° .032	73° .027	74° .022	74° .019	76° .014	77° .011	78° .009	79° .007
11	56° .150	57° .132	59° .117	60° .104	61° .092	63° .074	65° .060	67° .049	69° .040	70° .034	71° .028	72° .024	73° .021	75° .015	76° .012	77° .009	78° .007
12	53° .150	55° .133	56° .119	58° .106	59° .094	61° .076	63° .062	65° .051	67° .043	68° .036	69° .030	71° .026	72° .022	73° .017	75° .013	76° .010	77° .008
13	51° .148	53° .133	54° .119	56° .106	57° .096	59° .078	62° .064	63° .053	65° .044	67° .037	68° .032	69° .027	70° .023	72° .017	74° .013	75° .011	76° .008
14	49° .146	51° .131	52° .118	54° .107	55° .096	58° .079	60° .065	62° .054	63° .046	65° .039	66° .033	68° .028	69° .024	71° .018	72° .014	74° .011	75° .009
15	47° .142	49° .129	50° .117	52° .106	53° .096	56° .079	58° .066	60° .055	62° .047	63° .040	65° .034	66° .029	67° .025	69° .019	71° .015	73° .012	74° .009
16	45° .138	47° .126	48° .115	50° .105	51° .095	54° .080	56° .067	58° .056	60° .048	62° .041	63° .035	65° .030	66° .026	68° .020	70° .016	72° .012	73° .010
17	43° .134	45° .122	47° .112	48° .103	50° .094	52° .079	55° .069	57° .057	59° .048	60° .042	62° .036	63° .031	65° .027	67° .021	69° .016	71° .013	72° .010
18	42° .129	43° .119	45° .109	47° .100	48° .092	51° .079	53° .067	55° .057	57° .049	59° .042	61° .036	62° .032	63° .028	66° .021	68° .017	69° .013	71° .011
19	40° .124	42° .115	43° .106	45° .098	46° .090	49° .077	52° .066	54° .057	56° .049	58° .042	59° .037	61° .032	62° .028	65° .022	67° .017	68° .014	70° .011
20	39° .119	40° .111	42° .103	44° .095	45° .088	48° .076	50° .066	52° .057	54° .049	56° .043	58° .037	60° .033	61° .029	63° .022	66° .018	67° .014	69° .012
21	37° .114	39° .107	41° .099	42° .092	44° .086	46° .075	49° .065	51° .056	53° .049	55° .043	57° .038	58° .033	60° .029	62° .023	64° .018	66° .015	68° .012
22	36° .109	38° .102	39° .096	41° .091	42° .084	45° .073	47° .064	50° .056	52° .049	54° .043	55° .038	57° .033	59° .029	61° .023	63° .019	65° .015	67° .012
23	35° .105	36° .098	38° .092	40° .087	41° .081	44° .071	46° .063	49° .055	51° .049	53° .043	54° .038	56° .033	57° .030	60° .023	62° .019	64° .015	66° .013
24	34° .100	35° .094	37° .089	38° .084	40° .079	43° .070	45° .061	47° .054	49° .048	51° .042	53° .037	55° .033	56° .030	59° .024	61° .019	63° .016	65° .013
25	33° .096	34° .091	36° .086	37° .081	39° .076	41° .068	44° .060	46° .053	48° .047	50° .042	52° .037	54° .033	55° .030	58° .024	60° .019	62° .016	64° .013
27	31° .087	32° .083	34° .079	35° .075	37° .071	39° .064	42° .057	44° .051	46° .046	48° .041	50° .037	52° .033	53° .030	56° .024	58° .020	61° .016	63° .013
30	28° .077	30° .073	31° .070	32° .067	34° .064	36° .058	39° .053	41° .048	43° .043	45° .039	47° .036	49° .032	50° .029	53° .024	56° .020	58° .017	60° .014
33	26° .067	27° .065	29° .062	30° .060	31° .058	34° .053	36° .049	38° .045	40° .041	42° .037	44° .034	46° .031	47° .028	50° .024	53° .020	56° .017	58° .014
36	24° .059	25° .057	27° .055	28° .053	29° .052	31° .048	34° .044	36° .041	38° .038	40° .035	42° .032	43° .030	45° .027	48° .023	51° .020	53° .017	55° .014
40	22° .050	23° .049	24° .047	25° .046	27° .045	29° .042	31° .039	33° .037	35° .034	37° .032	39° .030	40° .028	42° .026	45° .022	48° .019	50° .016	52° .014
45	20° .041	21° .040	22° .040	23° .039	29° .038	26° .036	28° .034	30° .032	32° .030	34° .028	35° .027	37° .025	39° .024	42° .021	44° .018	47° .016	49° .014
50	18° .035	19° .034	20° .033	21° .033	22° .032	24° .031	26° .029	27° .028	29° .027	31° .025	33° .024	34° .023	36° .021	39° .019	41° .017	44° .015	46° .013
55	16° .029	17° .029	18° .028	19° .028	20° .027	22° .026	24° .025	25° .024	27° .023	29° .022	30° .021	32° .020	33° .019	36° .018	39° .016	41° .014	43° .013
60	15° .025	16° .025	17° .024	18° .024	18° .024	20° .023	22° .022	23° .021	25° .021	27° .020	28° .019	30° .018	31° .018	34° .016	38° .015	41° .013	43° .012
70	13° .019	14° .019	14° .019	15° .018	16° .018	17° .018	19° .017	20° .017	22° .016	23° .016	24° .015	26° .015	27° .014	30° .013	32° .012	34° .012	37° .011
100,000 CANDLEPOWER SOURCE																	
80	11° 14.748	12° 14.623	13° 14.491	13° 14.412	14° 14.269	15° 14.031	17° 13.708	18° 13.441	19° 13.161	21° 12.789	22° 12.489	23° 12.182	24° 11.870	27° 11.138	29° 10.492	31° 9.848	33° 9.212
100	9° 9.630	10° 9.571	10° 9.539	11° 9.474	11° 9.439	12° 9.330	14° 9.175	15° 9.048	16° 8.914	16° 8.819	18° 8.627	19° 8.475	20° 8.319	22° 7.993	24° 7.654	26° 7.305	27° 7.014
125	7° 6.250	8° 6.223	8° 6.209	9° 6.178	9° 6.163	10° 6.113	11° 6.059	12° 6.001	13° 5.938	14° 5.872	14° 5.828	15° 5.756	16° 5.681	18° 5.521	19° 5.384	21° 5.207	23° 5.022
150	6° 4.370	6° 4.364	7° 4.349	7° 4.342	8° 4.324	8° 4.309	9° 4.280	10° 4.249	11° 4.216	11° 4.195	12° 4.158	13° 4.119	14° 4.078	15° 4.008	16° 3.934	18° 3.834	19° 3 751
175	5° 13′ 3.225	5° 33′ 3.220	6° 3.213	6° 3.210	7° 3.199	7° 3.191	8° 3.174	8° 3.164	9° 3.145	10° 3.124	10° 3.112	11° 3.089	12° 3.064	13° 3.024	14° 2.980	15° 2.933	17° 2.869
200	4° 34′ 2.476	4° 52′ 2.473	5° 9′ 2.470	5° 26′ 2.468	5° 43′ 2.463	6° 2.457	7° 2.446	7° 2.440	8° 2.428	9° 2.415	9° 2.408	10° 2.393	10° 2.385	11° 2.360	12° 2.332	14° 2.294	15° 2.262

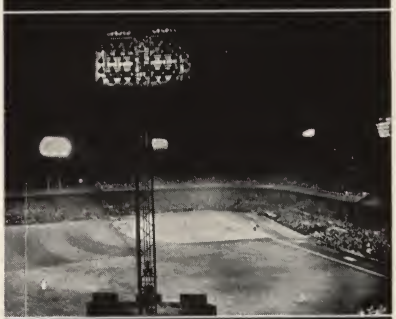
PART 4

FLOODLIGHTING
SPORTS LIGHTING

PART 4

FLOODLIGHTING
SPORTS LIGHTING




PART 4

FLOODLIGHTING
SPORTS LIGHTING

With a growing appreciation of its value, architects have found floodlighting an elastic medium of expression, illuminating engineers—a valuable lighting tool, and businessmen—an attractive and effective means of bringing attention to their enterprises. Modern floodlighting meets many utilitarian requirements as well as many applications concerned with decoration, esthetic, or advertising value. Protecting property after nightfall, completing a construction job within the time allotted, illuminating a dangerous traffic intersection, and prolonging the hours of play on recreational areas are only a few of the almost infinite applications of utilitarian floodlighting.

As an advertising medium that compels attention without detracting from the beauty or dignity of a building, floodlighting offers its best proof by the many excellent examples to be found in almost every city. The natural beauty of churches, civic buildings, monuments, and gardens is often enhanced by skillfully applied floodlighting.

Lighting Effects and Location of Projectors

The lighting effect to be obtained is generally dictated by available projector locations, architectural conformation and detail, type of business or institution, surroundings, and similar considerations. As the design of a new building evolves, however, the architect may well treat night illumination not as an after consideration but as an integral part of the final appearance of the building—which is coming to be considered as important by night as by day. Thus the lighting effect desired dictates the provision of suitable projector locations instead of the available projector locations dictating the lighting effect.

Small buildings of simple architectural treatment are generally most effective when floodlighted with uniform illumination by projectors placed on curbposts or on buildings not more than 200 feet away. This method of over-all illumination, free from shadows, tends to bring out the solidity, strength, and mass of the building.

Larger buildings and skyscrapers with setback features and towers offer floodlighting the opportunity to increase their apparent height and grace and to emphasize distinctive architectural features by tasteful use of shadow effects, and color if appropriate. The projectors are usually placed immediately inside and below the parapet of ledges formed by setbacks. In cases involving floodlighting of architectural or sculptural detail, the architect's viewpoint should govern.

Floodlighting of construction or recreation areas is chiefly a problem of providing light for seeing and the location of floodlighting projectors should be critically studied to eliminate glare resulting from a direct view of bright light sources in the usual field of vision.

Color

Floodlighting with color adds to ordinary exterior lighting the increased effectiveness of brilliant colors and subtle pastel shades. Attention-compelling, high in advertising value, and esthetically pleasing, color has been found to be a useful ally in floodlighting.

By the simple expedient of changing the colored cover glasses or filters on the projectors, a new artistry is introduced for the enhancement of buildings and monuments, fountains and gardens. Recently developed gaseous-discharge light sources are inherently colored and

consequently produce colored light many times more efficiently than by methods of absorption necessary with incandescent lamps. Although the use of gaseous-discharge lamps for floodlighting is not yet widespread, their higher efficiency as a source of colored light indicates more extensive use of colored floodlighting in the future.

Mobile Color

Floodlighting reaches its apex in beauty and effectiveness with the application of mobile color lighting. The idea of color that continually changes the aspect of buildings and fountains achieved almost immediate acceptance at its introduction, and a variety of excellent examples of this treatment are in service. The display of animated color attracts the attention and approval of everyone. With G-E Thyratron-reactor control, mobile color lighting becomes completely automatic. The striking beauty of many different color combinations can be obtained economically and can be accurately repeated in ever-changing procession without the use of cumbersome mechanical devices.

Design

The design of a floodlighting installation is the summation of a great variety of widely varying factors, each of which bears an important influence upon the resultant effect. The experience of the floodlighting engineer, the effect demanded by the architect, and the numerous uses of floodlighting for many different buildings and lighted surfaces are only a few of these factors. Although much of floodlighting practice can be reduced to factual data, the experience of those designing the installation will do a great deal to determine the final result. A few hours spent experimenting with various floodlighting projectors on different surfaces at varying distances is of great value in this connection.

The following tables and suggestions are intended as a condensed general outline of current floodlighting technique.

TABLE No. 9—FOOTCANDLE RECOMMENDATIONS FOR FLOODLIGHTING APPLICATIONS

Buildings and Monuments

Representative Building Materials	Approx. Reflection Factors, Per Cent	Footcandles for Downtown* Buildings in Cities of:		
		Over 50,000	50,000 to 5,000	Under 5,000
White Terra Cotta Cream Terra Cotta Light Marble	75	15	10	5
Light Gray Limestone Bedford Limestone Buff Limestone Smooth Buff Face Brick	50	20	15	10
Briar Hill Sandstone Smooth Gray Brick Medium Gray Limestone Common Tan Brick	35	30	20	15
Dark Field Gray Brick Common Red Brick Brown Stone	20	50	30	20

* For buildings in outlying districts use the footcandles recommended for downtown buildings in cities of the next smaller classification.

NOTE—Buildings composed of material having a reflection factor much below 20 per cent cannot economically be floodlighted unless there is a large amount of light trim.

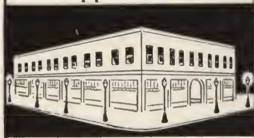
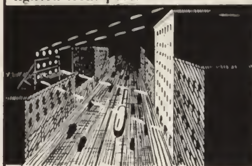
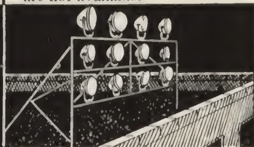
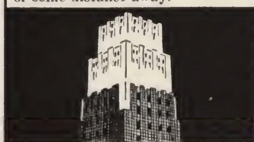
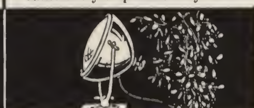
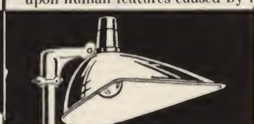
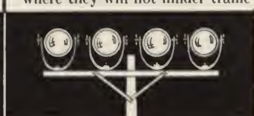
Utilitarian and Protective Purposes

Construction Work	5
Dredging	2
Gasoline Service Stations	
Buildings and Pumps	20
Yard and Driveways	5
Parking Spaces	1
Protective Industrial	0.2
Quarries	2
Shipyards (construction)	5

Special Applications

Trees	5–20
Flags	30
Loading Docks	5
Loading Platforms	5
Signs	30
Smokestacks	15
Art Glass Windows	20–200
Waterfalls	10
Water Tanks	15

A GUIDE TO THE SELECTION AND LOCATION OF EQUIPMENT

Representative Floodlighting Applications	Typical Projectors	Distance of Projector from Lighted Surface		Beam Spread of Projector	Type of Lamp
 Buildings two or three stories high lighted from posts at curb.	 Floodlights may be placed on curbposts or wide marquees to light small stores, theatres, etc., when suitable positions across the street are not available.	10–30 ft.		Wide	General Service
 Buildings lighted from across street or some distance away.	 When length of building face to be illuminated is not greater than distance of floodlights from building, the units can be placed in one group.		Lighted surface		
		50–100 ft.	less than 3000 sq. ft.	Medium	General Service
			more than 3000 sq. ft.	Wide	General Service
		100–150 ft.	less than 3000 sq. ft.	Narrow	Floodlighting
			more than 3000 sq. ft.	Medium	General Service
		150–300 ft.	less than 10000 sq. ft.	Narrow	Floodlighting
			more than 10000 sq. ft.	Medium	General Service
 Buildings of setback type.	 Units are placed immediately inside and below parapet and elevated sufficiently to permit easy maintenance and avoid drifting snow.	Height of Setback	One-story	Wide	General Service
			Two-story	Medium	General Service
			Three-story	Medium	General Service
			Four-story or more	Narrow	Floodlighting
 Columns, monuments.	 Best projector locations are most satisfactorily determined by trial. Statues usually require light from above to avoid grotesque effect upon human features caused by light from below.	2–100 ft.		Narrow	Floodlighting
 Small outdoor areas, gas stations, driveway approaches.	 Units should be mounted not less than 20 feet high and located where they will not hinder traffic or cause accidents due to glare.	At edge of Area		Wide	General Service
 Large outdoor areas, parking lots, etc.	 To insure that glaring light sources will not be in the direct line of vision, it is advisable to mount projectors as high as possible.	At edge of Area		Wide or Medium (Depending on length of throw)	General Service

Number of Projectors

Use the following formula to determine the number of projectors which will produce the required level of illumination—

$$\text{Number of projectors} = \frac{(\text{Area in Square Feet}) \times (\text{Footcandles})}{0.7 \times (\text{Beam lumens})}$$

Area—area of surface to be lighted, in square feet.

Footcandles—from Table 9.

0.7—this is the *Maintenance Factor* and represents an allowance of 30 per cent for depreciation in service.

Beam lumens—This figure will be obtained from manufacturers' catalogs for the specific equipment under consideration.

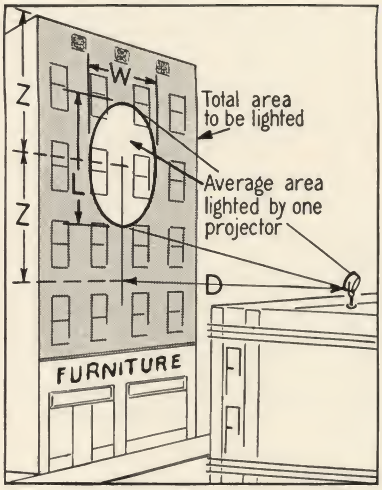


Table 10 below gives dimensions and areas covered by projectors of various beam spread at different distances and angles of throw. These data will be found useful where the use of a single projector is under consideration, or in checking for coverage where a group of projectors are used. The number of projectors required is obtained by dividing the total area to be lighted by the area covered by one projector.

The area of the spot is of principal concern in checking for coverage, but the length and width of the spot are useful in problems involving lighting of certain architectural details or in confining the light to limited areas.

The data apply whether the problem is that of lighting vertical surfaces, or whether the projectors are mounted on poles lighting an area on the ground, as indicated in the two sketches.

TABLE No. 10—SPOT SIZES—DIMENSIONS AND AREAS

(Representing average effective coverage for various beam spreads and locations of projectors)

		10° BEAM			15° BEAM			20° BEAM			25° BEAM		
D	Z	Area	Length	Width	Area	Length	Width	Area	Length	Width	Area	Length	Width
15	0	5	3	3	10	4	4	18	5	5	30	7	7
	10	8	4	3	20	6	5	33	8	7	50	10	8
	20	21	7	4	50	11	7	93	16	9	160	20	12
	30	52	14	6	130	21	9	250	30	13	460	41	17
	40	113	22	8	290	37	12	620	55	17	1300	83	23
25	0	11	4	4	25	7	7	44	9	9	70	11	11
	20	23	7	5	50	11	8	100	15	12	150	19	14
	40	71	16	8	170	25	13	330	34	17	540	45	22
	60	195	31	11	490	49	18	1030	73	25	1960	105	34
	80	450	54	15	1200	90	24	2920	145	36	7270	251	53
50	0	38	9	9	90	13	13	155	18	18	210	20	20
	20	47	11	9	110	15	14	195	21	19	320	26	24
	40	81	14	11	190	22	17	330	30	23	550	38	29
	60	150	22	14	340	33	20	630	45	28	1070	58	36
	80	260	32	17	600	49	25	1160	68	35	2060	90	45
75	0	67	13	13	170	20	20	310	26	26	480	33	33
	40	110	17	14	250	25	22	440	34	30	710	43	38
	80	220	28	18	540	43	29	1010	59	39	1630	75	50
	120	530	48	25	1210	74	38	2320	102	52	3930	135	67
	160	1040	76	32	2500	119	49	5050	171	67	9060	238	88
100	0	120	17	17	310	26	26	490	35	35	770	44	44
	40	150	20	19	390	31	28	610	41	38	980	52	48
	80	250	29	22	580	44	34	1050	59	46	1700	75	58
	120	470	43	28	890	66	41	2000	90	56	3290	116	72
	160	830	63	33	1950	98	51	3700	136	69	6340	180	89
	200	1300	80	42	....	...	...	6650	201	84	.....	...	...
150	0	270	26	26	610	39	39	1100	53	53	1740	67	67
	40	300	28	27	680	42	41	1230	57	55	1940	71	69
	80	400	34	30	900	51	45	1630	69	60	2580	87	76
	120	570	43	34	1310	65	51	2380	89	68	3820	113	87
	160	860	57	39	1970	86	58	3610	117	79	5920	151	100
	200	1280	74	44	....	...	...	5550	156	91	.....	...	...
200	0	480	35	35	1090	53	53	1940	71	71	3090	89	89
	40	510	37	36	1160	55	54	2080	73	72	3280	92	91
	80	600	41	38	1360	61	57	2470	82	77	3910	104	96
	120	770	48	41	1730	72	61	3160	97	83	5030	123	104
	160	1030	58	45	2330	87	68	4240	118	91	6800	150	115
	200	1370	71	50	....	...	...	5800	146	102	.....	...	...
300	0	1080	52	52	2460	79	79	4400	106	106	6940	133	133
	40	1110	53	53	2520	80	80	4520	108	107	7140	136	134
	80	1200	56	54	2720	85	82	4890	114	110	7740	143	138
	120	1350	61	57	3070	92	85	5530	123	114	8790	156	144
	160	1580	68	60	3590	102	90	6480	137	120	10300	173	152
500	0	3010	87	87	6810	132	132	12200	176	176	19300	222	222
	40	3030	88	88	6870	133	132	12300	177	177	19500	223	222
	80	3120	90	89	7070	135	133	12700	181	179	20100	228	225
	120	3270	93	90	7410	139	135	13300	187	181	21100	235	228
	160	3490	97	92	7900	145	138	14200	195	185	22500	246	233

When projector location is determined, the essential measurements are:

D = The distance from the projector to the plane of the lighted surface or area, measured perpendicular to the surface.

Z = This measurement determines the average angle of throw and consequently determines the average area covered by each projector. Two conditions apply:

1. If a perpendicular from the plane of the lighted surface to the projector falls *within* the total area to be lighted, Z = one-half the distance from the base of the perpendicular to the farthest edge of the surface to be lighted.

2. If a perpendicular from the plane of the lighted surface to the projector falls *outside* the total area to be lighted, Z = the distance from the base of the perpendicular to the mid-point of the total area to be lighted.

While these tables do provide an effective means of checking coverage, some designers prefer to lay out their design to scale with a protractor, which method gives both a check for average and a diagram for correct aiming of the projectors.

In computing the spot size, allowance has been made for necessary overlapping of beams from adjacent projectors.

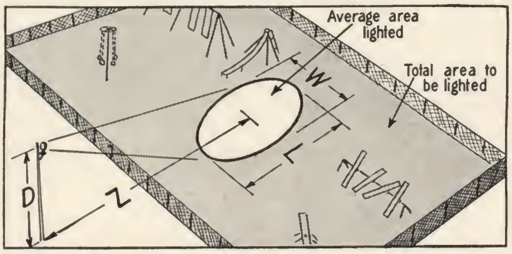


TABLE No. 10—SPOT SIZES—DIMENSIONS AND AREAS

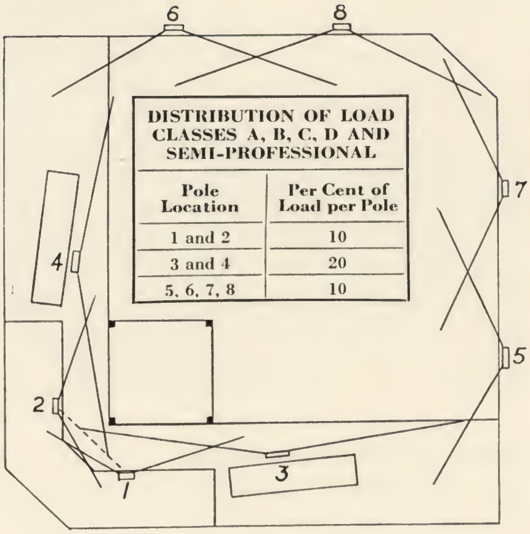
(Representing average effective coverage for various beam spreads and locations of projectors)

		30° BEAM			35° BEAM		
D	Z	Area	Length	Width	Area	Length	Width
15	0	45	8	8	60	9	9
	10	80	12	10	110	14	12
	20	240	26	14	360	32	17
	30	790	56	21	1430	79	27
	40	2900	133	33	8690	262	50
	...	....	...	...	....	...	...
25	0	100	13	13	140	16	16
	10	140	16	15	170	19	17
	20	220	23	18	310	28	20
	30	430	36	21	660	45	27
	40	920	59	28	1430	75	34
	50	1930	94	37	3270	131	45
	60	3950	155	46	8590	249	63
50	0	350	27	27	510	32	32
	20	450	33	29	650	37	34
	40	800	46	35	1160	55	41
	60	1590	73	44	2440	90	53
	80	3200	117	56	5300	151	69
	...	....	...	...	....	...	...
75	0	700	40	40	970	47	47
	20	790	43	42	1070	51	49
	40	1060	53	46	1460	63	54
	60	1590	69	53	2200	83	61
	80	2480	93	61	3620	114	73
	100	4000	128	72	5780	160	84
	120	6400	175	84	10100	226	103
100	0	1130	54	54	1560	63	63
	40	1430	63	58	1980	74	68
	80	2550	92	70	3560	110	82
	120	5050	146	89	7510	180	106
	160	10300	234	112	....	...	...
125	0	1760	67	67	2440	79	79
	40	2130	73	71	2870	88	83
	80	3090	97	80	4350	116	96
	120	5200	138	96	7430	167	113
	160	9140	200	116	....	...	...
150	0	2540	80	80	3510	95	95
	40	2880	86	85	3900	102	97
	80	3820	105	92	5300	125	108
	120	5700	135	107	8000	166	123
	160	10300	234	112	....	...	...
	...	.....	...	...	....	...	...
200	0	4500	107	107	6250	126	126
	40	4800	111	109	6660	132	129
	80	5700	125	116	7950	149	136
	120	7500	150	127	10300	178	148
	160	10200	184	141	.....	...	...
	...	.....	...	...	.....	...	...

		40° BEAM			50° BEAM		
D	Z	Area	Length	Width	Area	Length	Width
15	0	80	11	11	130	14	14
	5	110	13	12	175	17	16
	10	150	17	14	260	22	18
	15	310	25	19	530	33	25
	20	630	43	23	1250	63	30
	25	1150	65	27	....	...	...
25	0	185	18	18	305	23	23
	10	240	22	20	400	28	26
	20	450	33	24	800	44	32
	30	970	55	32	2050	83	44
	40	2300	98	42	6950	187	66
	50	6450	194	60	....	...	...
	....	...	...	...	....	...	...
35	0	320	26	26	520	33	33
	10	380	28	27	580	37	32
	20	510	35	32	890	47	39
	30	850	49	35	1550	67	47
	40	1490	71	43	3000	105	59
	50	2700	106	52	....	...	...
45	0	470	33	33	780	42	42
	10	520	35	34	820	44	42
	20	650	40	37	1070	52	47
	30	890	49	42	1550	67	53
	40	1320	66	46	2460	91	62
	50	2100	87	55	....	...	...
	...	....	...	...	....	...	...
55	0	640	40	40	1030	51	51
	20	790	46	44	1300	59	56
	40	1320	66	51	2330	88	68
	60	2650	104	65	5250	152	88
	80	5600	172	83	....	...	...
70	0	1020	51	51	1680	65	65
	20	1180	55	54	1940	72	69
	40	1680	71	60	2860	93	78
	60	2700	98	70	5000	135	94
	80	4700	142	84	....	...	...
85	0	1500	62	62	2460	79	79
	20	1680	67	64	2750	85	82
	40	2130	78	69	3600	102	90
	60	3080	100	78	5400	133	103
	80	4750	132	92	....	...	...
	100	7500	181	106	....	...	...
100	0	2100	73	73	3400	93	93
	20	2280	78	74	3700	98	96
	40	2700	86	79	4500	112	102
	60	3500	104	87	7800	138	113
	80	5000	130	98	....	...	...
	100	7300	168	110	....	...	...

SPORTS LIGHTING

BASEBALL



DISTRIBUTION OF LOAD CLASSES A, B, C, D AND SEMI-PROFESSIONAL

Pole Location	Per Cent of Load per Pole
1 and 2	10
3 and 4	20
5, 6, 7, 8	10

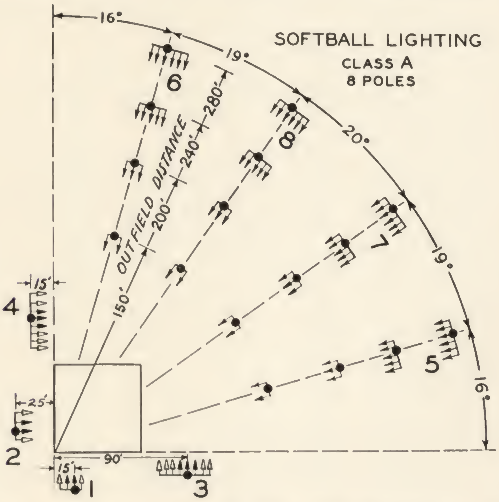
Location of poles is shown in diagram with the approximate distribution of the load on the poles for five classes of fields. These fields generally use the open-type reflectors. Major league fields and class AA fields require a much higher illumination and better control of light. For these fields floodlighting projectors or a combination of floodlighting projectors and open-type reflectors are used. When this combination is used, about 25 per cent of the load is required in floodlighting projectors, the majority of which are placed on poles Nos. 1, 2, 3 and 4 with only a few on the other poles to light the short center field.

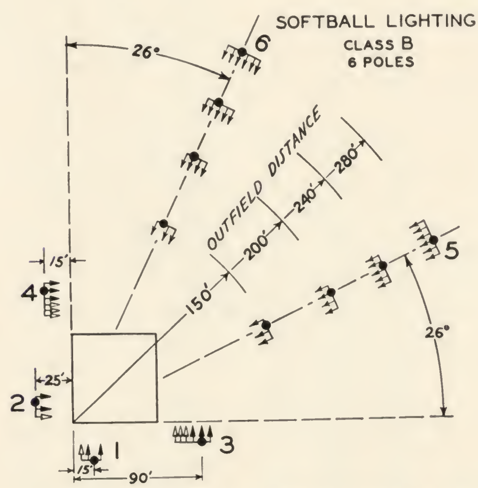
Class	Kw. Load at Normal Voltage	Mounting Height
Major League	750–1000	Open Units—100′ Min. Closed Units—120′ Min.
AA	400–600	Open Units—100′ Min. Closed Units—120′ Min.
A and B	200–350	80′—90′
C and D	175–250	70′—80′
Semi-Pro	100–150	60′—70′

SOFTBALL

The size of the audience, size of field, and the skill of the players are the principal factors which determine the kilowatts required.

Open-type reflectors with 1500-watt general service lamps are generally used, located as shown in diagram. Units on infield poles should be mounted 40 feet high, minimum. Outfield units should be 40 to 60 feet above ground depending on distance from home plate. See table for number of units on each pole.





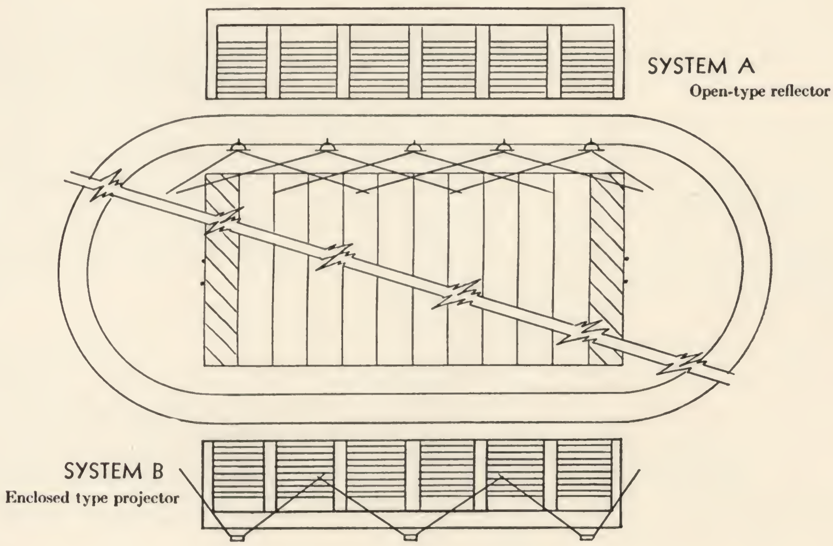
Distance from Home Plate to Outfield	Number of 1500-watt Lamps on Each Pole: Poles 1 and 2	Poles 3 and 4	Poles 5 to 8	Total Kw.
CLASS A (8 Poles)				
150′	2	3	2	27
150′—200′	2	4	3	36
200′—240′	3	5	5	54
240′—280′	4	8	6	72
CLASS B (6 Poles)				
150′	2	2	3	21
150′—200′	2	3	4	27
200′—240′	2	4	5	33
240′—280′	3	6	6	45
CLASS C (6 Poles)				
150′	2	2	2	18
150′—200′	2	2	3	21

Note—It is recommended that lamps be burned 10% over-voltage for sports lighting where the annual usage is less than 200 hours.

FOOTBALL

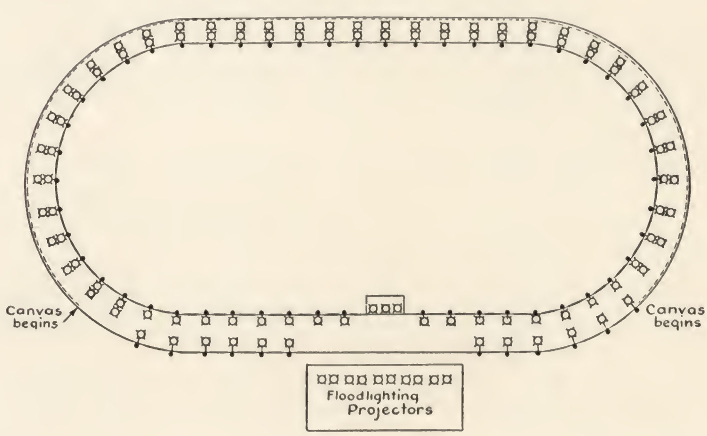
(A) High schools, small colleges—Five poles are erected on each side of field, 75 feet apart, about 45 feet high and approximately 15 feet from the side lines. Five to six kw. on each pole is minimum for small schools, six to twelve kw. for larger schools. Size of audience and skill of players determine the load. Open-type reflectors are commonly used.

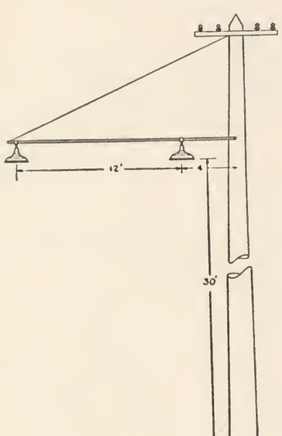
(B) Medium size stadiums—Six towers, three on each side are mounted behind or in back of the stadium, 70 to 90 feet above the playing field. The towers are spaced about 150 feet apart with 12 to 20 1000-watt floodlight projectors per tower.



RACE TRACKS

Sixteen-foot mast arms equipped with two 750-watt RLM Domes, as illustrated, are located on the inside of the track. On the home stretch use two rows of single 1500-watt units, one on inside, one on outside of track. On curves and backstretch two units per mast arm are placed four feet and 16 feet out from pole. White canvas on fence is commonly used in this area to silhouette horses so that they are easily visible from the grandstand. Floodlight projectors may be placed on the grandstand if needed to light the track in front of the grandstand where poles would obstruct view. Recommended spacing is 50 feet.

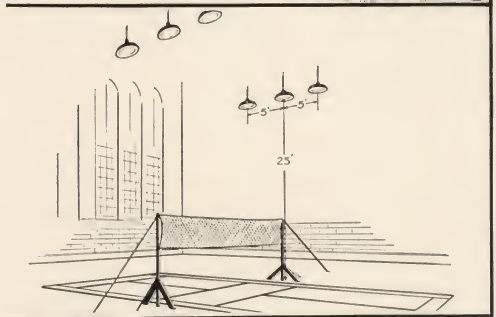




ARCHERY

This increasingly popular sport requires sufficient light not only to illuminate the target satisfactorily but also to light the area surrounding the target. Targets usually spaced about 10 yards apart for safety.

Type of projector—one narrow beam for each target. **Location**—directly behind and to left of archer, mounted 10 feet high. **Lamp size**—250-watt for average ranges, 500-watt for longer range.



BADMINTON

Because of the high flight of the bird, the lighting arrangement must avoid over-bright light sources in the players' eyes while looking upwards. Uneven levels of illumination will cause the bird to appear to hop or change speed in flight.

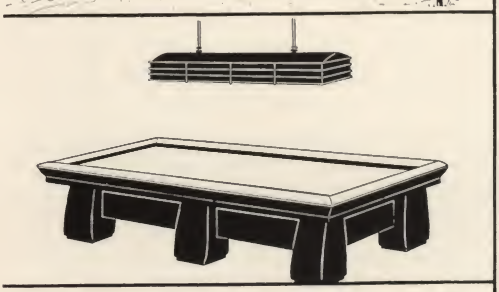
INDOOR: Type of unit—24-inch Glassteel. **Location**—three units, 25 feet high, at each end of net. **Lamp size**—750-watt. **Footcandles recommended**—25.

OUTDOOR: Type of reflector—two-socket open-type matte porcelain enamel. **Location**—one reflector at each end of net on 25-foot poles. **Lamp size**—750- or 1000-watt inside frosted. **Footcandles recommended**—25.

BATHING BEACHES

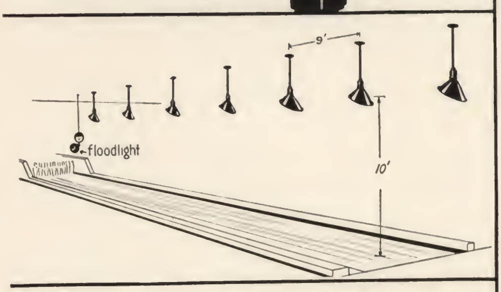
The swimming area as well as the beach should be illuminated. The size and type of beach determine projector locations, direction of beam, etc.

Type of projector—banks of narrow beam floodlighting projectors. **Location**—200 to 400 feet apart, mounted 40 to 80 feet high. **Lamp size**—1000-watt. **Footcandles recommended**—sufficient projectors located in each bank to provide approximately one footcandle evenly distributed.



BILLIARDS

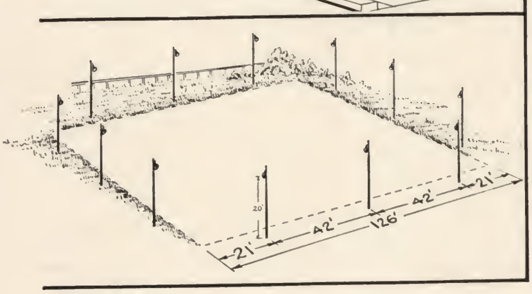
Type and location of reflectors—(A) Three 100-watt deep bowl porcelain or parchment reflectors spaced 3 feet apart along center line of table, mounted 5 feet above floor. (B) Where unobstructed view throughout room is desirable, a trough type housing with lens plates or aluminum parabolic reflectors with silvered bowl lamps may be used. Four 100- or 150-watt lamps spaced 1½ feet apart will give good concentration of light at mounting heights up to 10 feet.



BOWLING ALLEYS

Requires good uniformity of illumination along each alley, with light sources well shielded from players. Additional supplementary floodlighting should be provided directly on the pins, usually supplied by a 200-watt projector mounted above and a little ahead of the pins.

Type of reflector—angle type. **Location**—9 feet apart on center line of each alley and about 10 feet above alley as illustrated. **Lamp size**—150-watt. **Footcandles**—on alley 10; on pins 25.

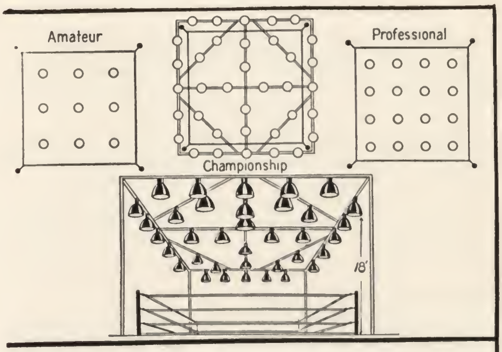


BOWLING on the GREEN (126' x 126')

The court should be fairly uniformly lighted to about 5 footcandles and from a sufficient number of sources so as to minimize long sweeping shadows.

SIDE LIGHTING: Type of reflector—elliptical angle. **Location**—21 feet from the ends, 42 feet apart on each of the four sides, and five feet or more outside the boundaries of the green. **Lamp size**—750-watt. **Mounting height**—20 feet.

OVERHEAD LIGHTING: Type of reflector—RLM Domes. **Location**—25-foot centers, strung 25 feet above green on messenger cables. **Lamp size**—500-watt.

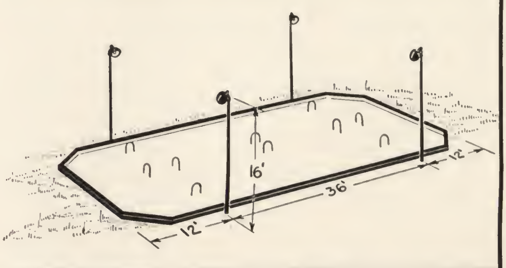


BOXING

The level of illumination required for boxing is dictated by such considerations as the size of the audience, importance of bout, and whether or not motion pictures are to be taken.

CHAMPIONSHIP: Type of reflector—open concentrating. **Location**—36 units, 18 feet above the ring and spaced as shown in sketch. **Lamp size**—1000-watt. **Footcandles recommended**—500 or more.

AVERAGE BOUTS: Nine or sixteen 1000-watt units, according to the bout's importance, uniformly spaced above ring to produce 100 or 200 footcandles. Other specifications are identical with those for championship exhibitions.

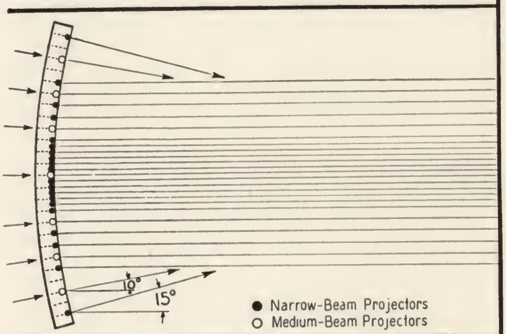


CROQUET or ROQUE (30' x 60')

Good lighting must be uniform and free from shadows for the accurate execution of difficult shots. Five footcandles recommended.

(A) **SIDE LIGHTING: Type of reflector**—open-type angle. **Location**—12 feet from the end of the court, 36 feet apart, and mounted on 16-foot poles as illustrated. **Lamp size**—500-watt.

(B) **OVERHEAD LIGHTING: Type of reflector**—RLM Domes. **Location**—strung on messenger cables 25 feet above the court on 15-foot centers. **Lamp size**—300-watt.



GOLF DRIVING RANGE

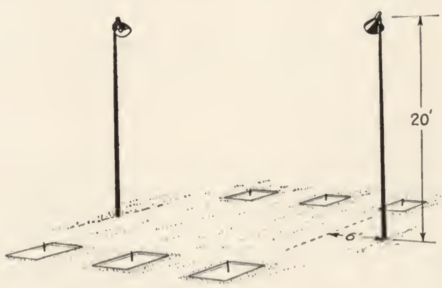
Short high shots as well as long, powerful drives must be illuminated so that players may follow the ball throughout its flight.

Types of projectors—(1) High candlepower narrow angle for long drives, (2) Medium angle for short high shots. **Location**—one projector for each tee with no less than a total of nine projectors for any driving range. About one-fourth of the units should be medium-angle projectors. **Mounting height**—approximately 15 feet. **Lamp size**—1000-watt G-40 for narrow-angle projectors, 1000-watt PS-52 for medium angle.

HOCKEY (Outdoor)

The extremely fast action of hockey requires at least 10 footcandles of illumination to enable both players and spectators to follow the puck throughout the rink. The units should be located just outside the rink to prevent slush and water from dripping on the ice and causing rough spots.

Type of projector—two floodlighting projectors or open-type reflectors per pole. **Location**—mounted at 25 feet and spaced about 50 feet apart. **Lamp size**—1000- or 1500-watt. Footcandles recommended—10.

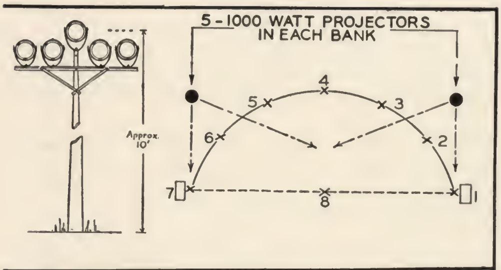


HORSESHOE COURTS

(A) **FOR ONE TO THREE COURTS: Type of reflector**—elliptical angle. **Location**—on 20-foot poles as illustrated. **Lamp size**—300- or 500-watt.

(B) **FOR MORE THAN THREE COURTS:** Place, in addition, one RLM Dome with a 300-watt lamp on a 20-foot pole halfway between the pitching lines and midway between the pits of two adjacent courts.

Large groups of courts may also be satisfactorily lighted with large open-type reflectors and 1000-watt lamps in the same relative position as shown in sketch. Ten footcandles are recommended.

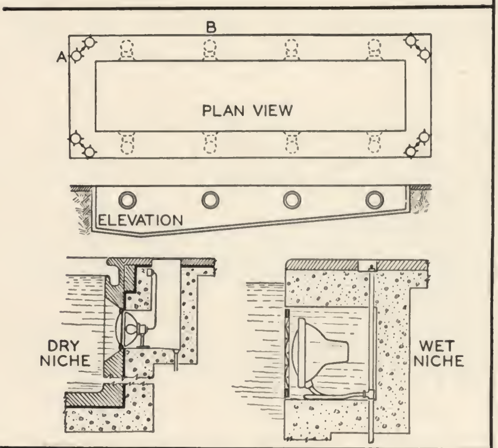


SKEET

In skeet, the flight of the clay pigeons is intended to duplicate the angles of flight found in actual wing shooting. Floodlighting projector beams are crossed to eliminate distorting shadows.

Type of projector—medium angle 40° spread lens. **Location**—about 25 feet back of shooting line at a height of approximately 10 feet. **Lamp size**—1000-watt.

Above each shooter's stand, except at station No. 8, place one 100-watt lamp in an RLM Dome to facilitate loading and aiming.



SWIMMING POOL

(A) **For Surface Lighting Equipment**—two open-type floodlighting projectors, or two enclosed projectors with heavily stippled clear glass doors. **Location**—at each corner of the pool on 25- to 40-foot poles. **Lamp size**—1000- or 1500-watt.

(B) **Under Water Lighting**—If water is sufficiently clear to see the bottom 10 feet below the surface in daylight, underwater lighting will be satisfactory. Two classes of underwater lighting are:

(1) **Dry niche**—500-watt projectors with 40° spread lenses, spaced not more than 12 feet apart on each side of pool 1 to 1½ feet below the water level. Manhole to be provided for servicing.

(2) **Wet niche**—Same as above except that underwater equipment is necessary. Units are mounted 1 foot to 1½ feet below water level. Front of niche should be protected by bull mesh. Because of the flexible hose and conductor, this type of wet niche unit makes possible cleaning or replacement of lamps without draining pool.

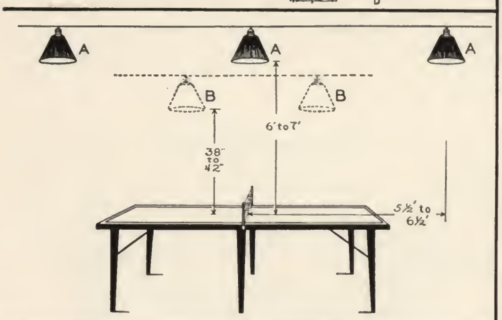
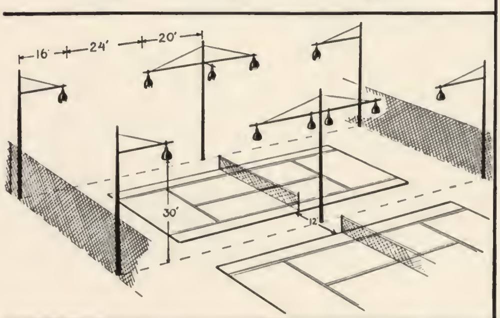


TABLE TENNIS

Lighting requirements are simple but for full enjoyment of the game, 30 or 40 footcandles are needed in order to follow the small white ball in its speedy back-and-forth motion.

Type of reflector—special parchment shades with large shielding angle. **Location**—three to seven feet above table and spaced as illustrated. A–for tournament play. B–for recreational play. **Lamp size**—150-watt.



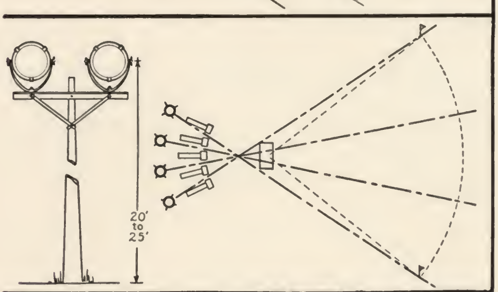
TENNIS (Outdoor)

For full enjoyment the light sources must be well shielded and illumination of the order of 20 to 30 footcandles should be provided.

(A) **SINGLE COURTS: Type of reflector**—wide angle, deep bowl aluminum with skirt. **Location**—mounted 30 feet high on brackets with poles located as shown. **Lamp size**—1500-watt for recreational play; 2000-watt for championship.

A string of five 1500-watt units on messenger cable along the center line of each court is reasonably satisfactory for recreational play.

(B) **TWO OR MORE COURTS:** Layout and specifications same as for single court but the inner rows require six reflectors without the shielding skirts.



TRAP SHOOTING

Floodlighting stations are placed on either side of shooting platform. The beams from each station are crossed to eliminate shadows. Stray light on platforms is sufficient to sight guns and to facilitate changing positions. **Type of projector**—eight medium beam floodlighting projectors. **Location**—four poles (2 projectors per pole) mounted 20 to 25 feet high behind shooting platform. **Lamp size**—1000-watt.

PART 5

LUMINOUS ARCHITECTURAL ELEMENTS

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LUMINOUS ARCHITECTURAL ELEMENTS

The photographs on this page exemplify the purpose and application of luminous elements. Not only do such structures embrace new interest and commercial value, but they are in key with the new materials and methods which have inspired the creation of new styles and induced fresh viewpoints of architectural design. It is noteworthy that one might choose equally representative designs from Europe, Japan or South America. The world-wide acceptance of luminous treatment in exterior and interior architectural composition is recognition of the vitality and charm of light as an expressive medium.

Composition

The employment of luminous elements whether for exterior or interior use is bounded only by design ingenuity striving for individuality, beauty and fluidity of composition that perpetuates interest and attention. Luminous exterior elements achieve for small commercial buildings a trim, chaste simplicity, combined with effective advertising and appealing individuality; for large monumental buildings, they bespeak a technique as significant to a stainless steel age as was the vaulted arch or flying buttress of centuries ago.

Luminous elements are necessarily custom-tailored to each application, the artist designer looking to the coordination of mass, line and general fitness while the lighting technician, with prime attention to light control, is charged with attainment of efficiency, arrangement and wattage of lamps, and their coordination with materials to produce desired brightness, uniformity, or any special effects sought.

The Design Problem

Variables and Limitations

No general set of design data can possibly embrace all of the variables encountered in custom-built lighting equipment, particularly where space limitations or specified materials force inevitable compromise with best engineering practice. It is impracticable, if not quite impossible, for example, to produce uniformity over an expansive background from lamps set close to the border; similarly, it is almost futile to attempt uniformity of frosted or light opalescent glass panels where the cavity depth is limited and where clear or frosted lamps must be located directly behind the glass.

There are, however, many forms of luminous elements representing all but the exceptional designs which fit into logical groupings for which basic design data apply. For radical departures from usual forms it is best, of course, to construct scale models to pre-test both design and the effect. It is believed that the data given herein will cover a great majority of design applications, where the requirement is for substantially uniformly lighted elements. Other effects, though mentioned, do not yield so readily to handbook methods.

LUMINOUS EFFECTS

A. Uniform Brightness—Most prevalent requirement. *Where lamps are directly behind glass* use highly diffusing materials (such as cased opal, solid opal or translucent white or colored plastics). Do not use frosted or light opalescent glasses or other low diffusion materials. *With shielded lamps behind glass* use any type of translucent material—the more carefully shielded the lamps, the less diffusion necessary in the translucent material which acts more as a cover plate for the luminous reflecting background. For uniformly bright reflecting surfaces matte or semi-matte finish is desirable.

B. Graduated or Shaded Brightness—Most interesting and decorative particularly if color is used. Results from lighting only from one direction, or excessive spacing between rows of lamps. Use highly diffusing glass if lamps are directly behind glass; if shielded use any type of material. With reflecting surfaces the shading is governed by the position of the shielded lamps, the cross-section of the surface and its finish.

C. Banded Effects—Highly interesting and spectacular particularly if color is used. With lamps behind glass, use ribbed or fluted glass. For reflecting backgrounds use metals such as stainless steel, polished aluminum or chromium with corrugated, brushed or ground surfaces. The bands are always at right angles to the direction of the brushing or corrugations; or, in the case of glass, to the flutes or ribbing. The width of the bands corresponds to the size of light source, the more diffusing the surface, or the source, the softer the effect.

D. Spotty Brightness Effect—For sparkle, and highlights, use low diffusion materials with lamps directly behind. For softer spots use materials of higher diffusion with lamp spacing relatively great. Arrange sources in pattern; random spotting is not usually desirable. Not effective for sign letter background but may prove interesting as a background for grilles or tracery silhouettes.

Color Effects—Attainable in all forms of elements—color may be incorporated either in the reflecting surface, the translucent material or the lamps, depending upon whether a difference is desired in day and night appearance, and whether changing color is to be introduced. For equal advertising effectiveness when colors are used, lamp wattage computed for white light should in general be increased as follows: amber—same as white; green—1.5 times; red—2 times; blue—4 times.

TABLE No. 11
SUGGESTED AVERAGE BRIGHTNESS VALUES—FOOT-LAMBERTS*

Exterior Applications

The selection of brightness levels is influenced by the following conditions:

1. Character, size and brilliance of immediately adjacent (competitive) displays.
2. Signs as such should always be brighter than other portions of a design.
3. Character of the institution. A conservative business will require less bright displays than a theatre, for example.
4. Relations in brightness of an element to another of the same display, for the purpose of producing emphasis or a design in brightness.
5. Extent of entire pattern and size of the elements. Lower brightness may suffice when scale is large.
6. In color, a lower brightness often proves effective.

TYPE AND APPLICATION OF LUMINOUS ELEMENT	General Brightness of District		
	Low	Medium	High
	Foot-Lamberts		
Decorative Flush Elements (Principal Units in Design) (Includes Panels and Recesses)	30–100	50–150	100–300
Decorative Projecting Elements (Principal Units in Design)	50–130	70–170	150–300
Decorative Elements, as, Spandrels and Niches (Particularly when subordinate elements in design)	30–60	40–80	50–150
Luminous Background Signs	90–150	120–200	150–350
Luminous Letter Stroke Signs	150–200	200–400	300–600
Small Luminous Facades (As small entirely luminous store-fronts and buildings)	80–120	100–150	120–200
Marquee and Entrance Soffits and Marquee Fascias	80–150	100–250	200–400
Luminous Beams under Canopies and Marquees (Restricted size, as for gasoline service stations)	150	250	400
Pylons (As for gasoline service stations, entrance markers, etc.)	100	200	300

Interior Applications

Factors which influence the selection of a limiting brightness for elements:

(a) **Contrast with surrounding surfaces.** Too great a contrast produces an unfavorable appearance, hence the brighter the surroundings, the higher can be the brightness of the elements.

(b) **Illumination in the room.** For equal glare effect, the illumination must be increased by 10 times to permit doubling the brightness of the units.

(c) **Position of elements.** They may be brighter when mounted high out of the usual field of view or when their light is not directed toward the observer.

(d) **Casual or prolonged viewing.** Higher brightnesses are acceptable where people are passing than where they are in one position for a considerable period as in an office or auditorium.

(e) **Size of luminous area.** As luminous area is increased, the brightness selected should be lower. Especially true of elements in walls.

	Foot-Lamberts
(a) Protruding ceiling elements, 20 feet or more above floor	500
(b) For elements in low ceilings, particularly in larger rooms (lower over mezzanine)	250
(c) Wall panels or recesses in passages	200
(d) Wall panels and niches not usually in line of sight	125
(e) Decorative panels constantly in view	75

* The foot-lambert is a unit of brightness equal to the average brightness of any surface emitting or reflecting light at the rate of one lumen per square foot, or the uniform brightness of a perfectly diffusing surface emitting or reflecting light at that rate. For a diffuse reflecting surface the average brightness in foot-lamberts is therefore the product of the incident illumination in footcandles and the reflection factor of the surface.

Brightness expressed in candles per square inch may be reduced to foot-lamberts by multiplying by 452.

One foot-lambert is equal to 1.076 millilamberts.

REFLECTING MATERIALS

The choice of materials for luminous reflecting elements is governed, from an architectural standpoint, by structural fitness, texture, color and permanence; from a lighting standpoint by light-reflecting efficiency and the light distribution characteristics of the finish, considered together with the form and position of the element and probable angles of view.

Common Building Material—Stone, concrete, terra-cotta, plaster and matte-finished porcelain and painted surfaces present a range of reflecting materials varying widely in reflecting efficiency. The diffuse distribution of light makes for uniform brightness of surface at most viewing angles.

Glazed and Enameled Materials—Glazed terra-cotta, structural glass, polished marbles, glass paint, and shiny porcelain enamel—present a range of reflecting efficiency, depending on color. They produce generally diffuse reflection but with a highly specular surface reflection of 5-10% of the light which mirrors the light sources causing annoying striations, streaks, and reflected images of the lamps. Except for special effects, matte-finished materials are more satisfactory.

Polished Metals—Stainless steel, chromium, aluminum and the like, offer a range of reflecting efficiency with a high degree of light control. Generally used where directional control of light and high brightness are required at specific angles of view. This control is largely lost if used behind highly diffusing cover glasses; well maintained with frosted, or stippled glass and other low diffusion transmitting materials. Very effective for special lighting effects where the surfaces are brushed, corrugated or otherwise configurated.

The efficiency data given for the various transilluminated elements (Table 12) assumes a reflection factor of 0.75 for internal reflecting surfaces. The importance of a high reflection factor for these parts is illustrated by the following data for a white cased opal glass panel.

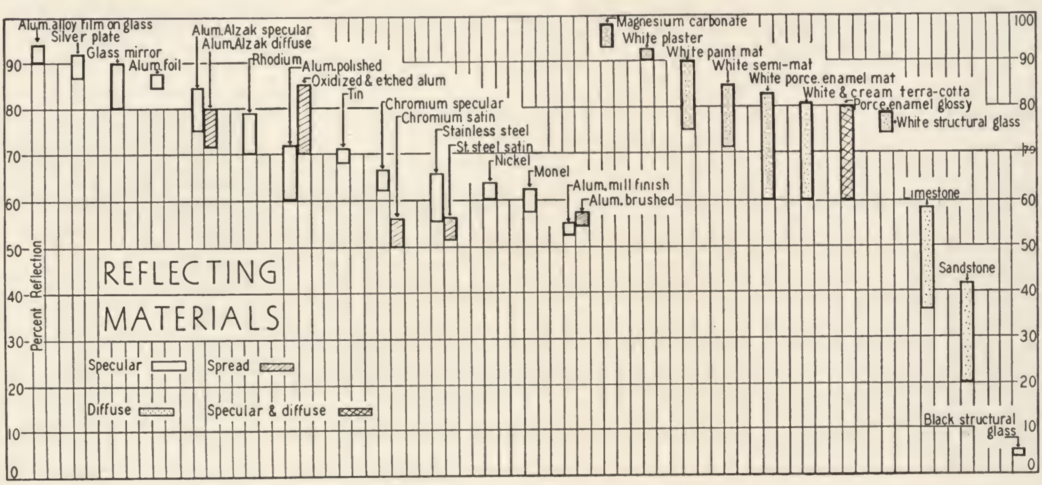
Reflection Factor of Cavity Surface	Relative Brightness and Efficiency
0.85	122%
0.75	100%
0.50	63%
0.25	40%

Specular or Mirrored

Spread

Diffuse or Matte

Diffuse—Specular



TRANSMITTING MATERIALS

Translucent materials run the complete range of transmission efficiency from about 95% for clear glass down to but a few per cent for colored marbles, with an equally wide range in light-diffusing characteristics. As in the case of reflecting materials the choice of transmitting materials is governed (a) by color, texture, and appearance, lighted and unlighted; (b) by efficiency, diffusing properties, and maintenance.

Highly Diffusing Materials—For luminous areas with apparently uniform brightness at all angles of view, highly diffusing materials are necessary, except where the incident light itself is highly diffused. Highly diffusing materials include homogeneous and cased opal and enameled glasses, plastics, marbles, and certain weights of paper and treated fabrics.

Low Diffusion Materials—Include such glasses as clear, frosted, configurated, alabaster and opalescent; also, thin gelatines and plastic sheets, light density papers, scrim and similar light woven fabrics. Usually chosen for texture when unlighted; when lighted, for sparkle, highlights, or other qualities to produce special lighting effects.

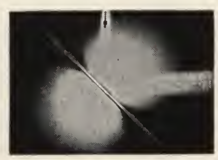
Unlighted Appearance

The choice of translucent materials is influenced also by their appearance outdoors in daytime or when unlighted indoors. Here the amount of light reflected is of special importance. The higher the reflection factor, the whiter the surface will appear in daylight, assuming largely diffusing characteristics. For example, if a definitely white surface is desired, a homogeneous opal glass should be used. The cased opals, opalescents, matte surface and configurated glasses assume progressively grayer tones. Texture and color may be a consideration.

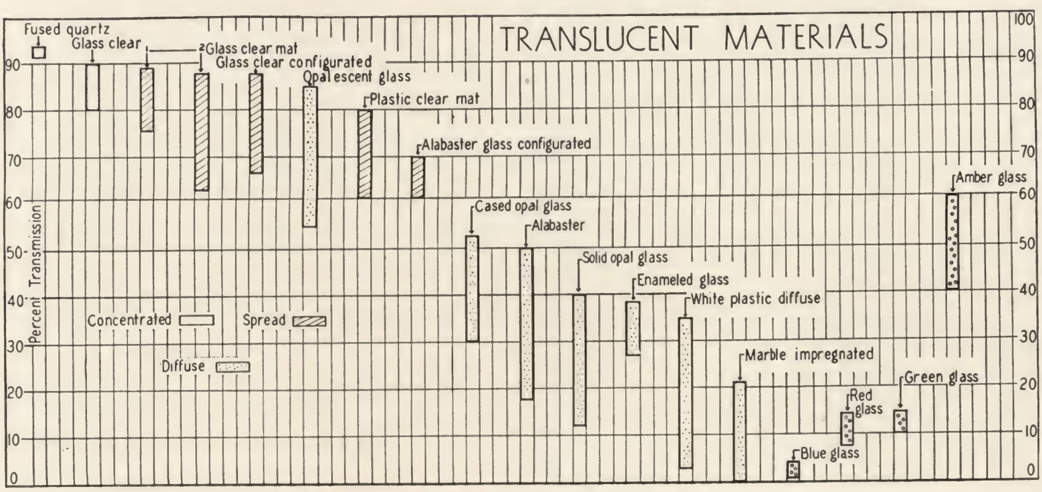
Obviously, selection involving this factor may entail more or less sacrifice of luminous efficiency, and in some cases, revision of element form to preserve the character of the desired luminous effect.

Ribbed or Prism

Spread



Diffuse



LIGHTING AND DESIGN PROCEDURE

The lighting design problem is set up by the designer who in his general plans has incorporated one or more luminous areas of a definite form and size. The exact type of element may be only tentative. The design problem is then first of settling on the best type—whether a simple background, an open cavity, or some form of enclosed element. The reflecting and transmitting materials must be selected. With these factors definitely established, the lighting engineer can proceed to work out the arrangement and size of lamps to produce the desired luminous effect. All conditions are then established for determining the efficiency of the element and establishing the size of lamp necessary to produce the selected brightness. Brief discussions of important considerations follow.

Type of Element Used

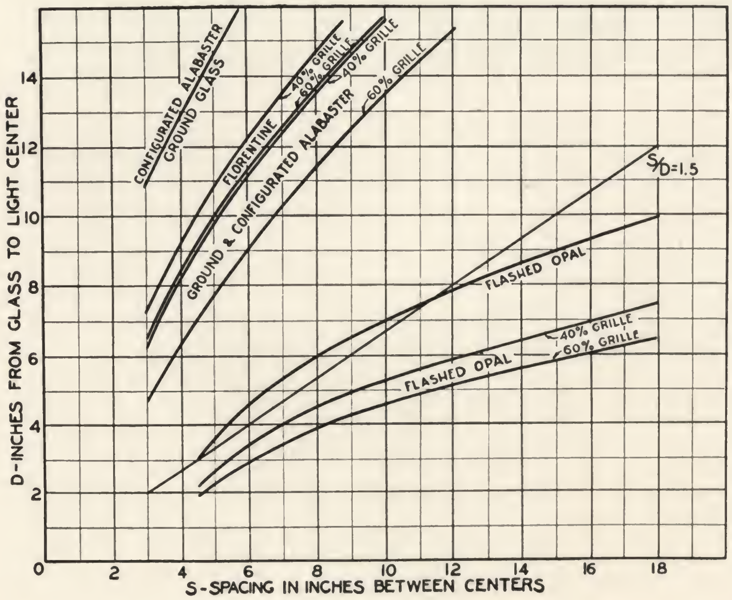
The type of element to be used is primarily a matter of architectural design, the choice being influenced by the space or recess depth available, structural requirements, the selected material and the desired ultimate luminous effect. Obviously the coordination of such factors dictates close cooperation between designer and lighting engineer in the early stages of the project to insure effective results.

Spacing of Lamps for Uniform Distribution of Brightness

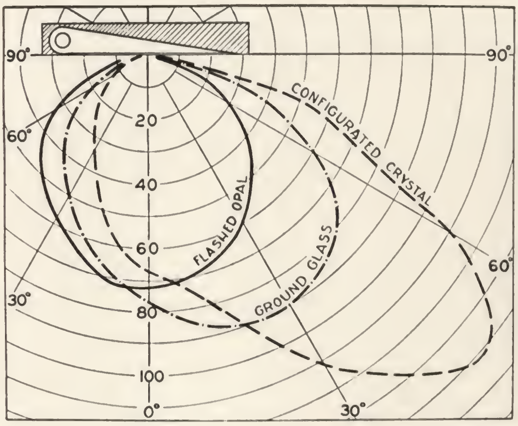
Where lamps are placed behind diffusing glass the maximum permissible spacing between lamps follows the common rule for general lighting, i.e., a spacing of 1½ times the distance of the filament back of the glass. Variations from this rule for glasses of various diffusing properties and for various sizes of panel are shown by the curves in chart below. Where lamps are placed in silhouette troughs or miniature coves at the sides of the luminous area, the spacing of lamps concealed within the trough as well as the distance between troughs is subject to the same general rule though variations are permissible in particular cases.

Graduated or Shaded Brightness

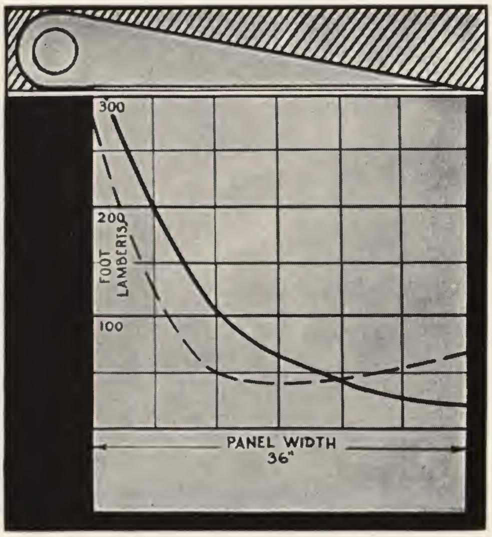
The graduation of brightness is primarily the result of element form and the position of the rows of lamps with respect to the luminous surface. Shaded or non-uniform brightness can hardly be reduced to specification form because of the great variety of effects to be obtained. The drawings on page 61 give an indication of the degree of shading obtained in one type of element with stated materials. The lamp spacing in a row generally



Lamp spacing for acceptable uniformity of brightness. With grilles or decoration on the glass lesser uniformity is permissible.



Light distribution from a luminous element lighted from a row of lamps at one side when covered by (1) flashed or cased opal glass, (2) ground or frosted glass and (3) by configurated or obscure crystal glass, indicating relative brightness values at any given angle.



Also, an element of this form will produce a graduation of brightness across the width of the panel when viewed normal to the surface. This graduation is indicated by the shading on the sketch above, for a panel 36 inches wide. The solid line indicates the brightness gradient for cased opal and sand-blasted glass with the above element form, and the broken line gradient for configurated or obscure crystal glass with a gently curved internal reflecting surface.

follows that used for uniformly bright elements, since the object is to provide uniform brightness distribution in one direction and shading in the other.

Element Forms and Efficiencies—(Table No. 12)

A typical selection of luminous elements is presented in Table No. 12. These elements may, of course, be applied in many ways in various locations. The sketches are intended only to illustrate the luminous form; structure and details vary. The performance of other forms may in many instances be estimated by comparison with those shown. Size of the actual elements will vary.

For each element a group of defining ratios are given. They are based on the *width of the element* (W). Those for *distance from surface to light source* (D), and *spacing between light centers of lamps* (S) are based on the condition of apparent uniformity of brightness distribution in one or both dimensions of the luminous surface. When brightness is uniform in one direction only, graduated brightness obtains. Another ratio gives the *luminous area per lamp* (in square inches) in terms of (W) and (S).

For each element is given the approximate luminous efficiency for various materials in terms of: reflection factor (diffuse) in the case of reflecting elements, and, transmission factor in the case of transilluminated elements. In the latter case, efficiencies are based on internal surfaces reflecting 75% of the light. Similarly, where troughs concealing lamps are used, their surfaces are assumed to be diffusing with 75% reflection.

When the most practical type of element has been established, lay out a scaled cross-section and indicate the position of the rows of lamps. Calculate to find (D) and (S) from the ratios as given, then determine the luminous area per lamp (A).

SELECTING LAMP SIZE (Table No. 13)

(Determine from the table the *efficiency* corresponding to the element form chosen and the reflection or transmission factor of the selected material.)

For a given element of known area-per-lamp and efficiency, the lamp wattages to produce a certain average brightness in foot-lamberts may be obtained directly from Table 13. At the left of the table is *area per lamp, lamp wattage and lumen output;* at the top is *efficiency.* A maintenance factor of .70 has been assumed in the calculations of foot-lamberts.

Note that—

(a) In an element of given size, efficiency and lamp spacing, average brightness varies in direct proportion to lumen output of the lamps.

(b) In an element of given size and efficiency, average brightness varies in inverse proportion to lamp spacing.

(c) In an element of given efficiency and lamp size, average brightness varies in inverse proportion to *area per lamp.* This enables one to determine the resulting average brightness for areas-per-lamp other than those given in the table. The average brightness values are independent of degree of uniformity of brightness distribution.

TABLE No. 12—ELEMENT FORMS AND EFFICIENCIES IN PER CENT

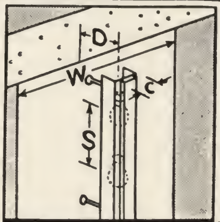
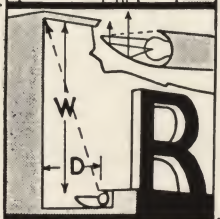
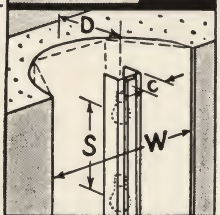
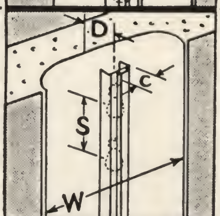
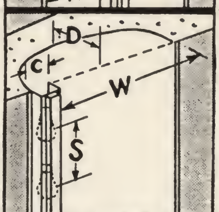
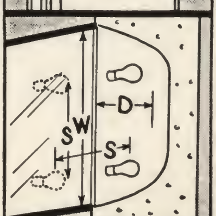
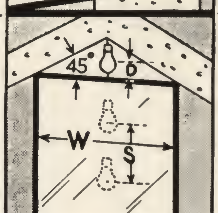
TYPE OF ELEMENT		Dimensional Ratios	REFLECTION OR TRANSMISSION FACTOR 0.20	0.30	0.40	0.50	0.60	0.70	0.80	
			ELEMENT EFFICIENCY							
1		D = 0.33 W S = 0.50 W S = 1.5 D A = (W − C) S	8	12	16	20	24	28	32	Width based on 5 to 1 variation of brightness from center to edge. Concavity of surface produces greater uniformity of brightness; convexity increases shading. In design of cross-section trough cut-off and angle of view are very important.
2		D = 0.25 W S = 0.56 W S = 2.25 D A = WS	7	10	13	17	20	23	27	Requires polished metal parabolic trough reflectors with maximum candlepower directed to the far edge of surface. With ratios given brightness graduations will be of the order of 25 to 1; the degree of shading can be lessened by the use of a larger, more concentrating reflector, and by increasing D with respect to W.
3		D = 0.5 W S = 0.95 W S = 1.9 D A = (W − C) S	12	17	23	28	34	40	46	Produces a sharply defined luminous area; lamp filament is located in plane of opening. Range of effects attainable—uniformity with diffusing background, sparkle, glitter or banded effects with crinkled, fluted, or brushed metallic background.
4		D = 0.17 W S = 0.25 W S = 1.5 D A = (W − C) S	10	15	20	25	30	35	40	Shallow cavities produce slightly graduated brightness; as in No. 3 a range of effect is attainable by choice of material and finish of background. Check dimensions with physical size of lamp used to insure ample allowance for inserting lamps.
5		D = 0.33 W S = 0.33 W S = D A = (W − C) S	7	10	13	17	20	23	27	Slightly graduated brightness produced by lamps at one side; uniformity if lamps are located on each side with a ratio as given. In small elements make certain that dimensions allow for easy lamp replacement.
6		(For 2 rows of lamps) D = 0.33 W S = 0.50W S = 1.5 D A = 0.50 WS	25	35	44	51	56	61	65	Representative of a great variety of forms ranging from a narrow band requiring a single row of lamps to large expanses of luminous glass areas requiring a wide variety of lamp arrangements. Efficiencies vary slightly with size and form, but spacing between lamps should conform to the cavity depth and type of translucent material used.
7		D = 0.40 W S = 0.60 W S = 1.5 D A = WS	26	37	46	54	60	66	70	Lamps should be placed in the corner to permit wider spacing and better lateral uniformity of brightness with highly diffusing materials. A slight shading of brightness at the sides may be noticed. In small elements tubular or Lumiline lamps placed end to end conserve space.

TABLE No. 12—ELEMENT FORMS AND EFFICIENCIES IN PER CENT

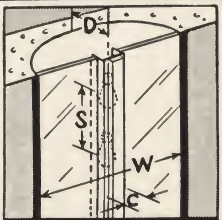
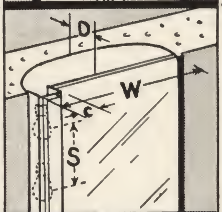
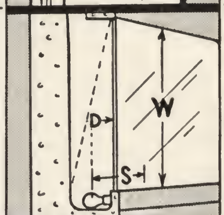
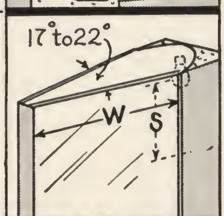
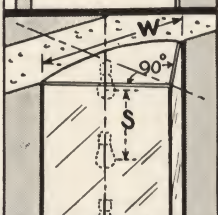
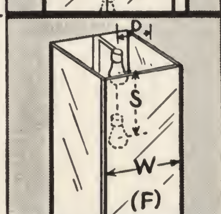
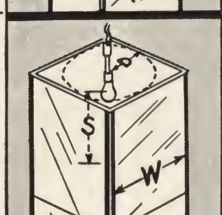
TYPE OF ELEMENT		Dimensional Ratios	REFLECTION OR TRANSMISSION FACTOR 0.20	0.30	0.40	0.50	0.60	0.70	0.80	
8		D = 0.33 W S = 0.66 W S = 2 D A = (W − C) S	ELEMENT EFFICIENCY 13	17	21	25	29	33	37	Indirectly-lighted transilluminated elements of this character may use any type of translucent material, the choice being governed by the unlighted appearance, texture and efficiency.
9		D = 0.17 W S = 0.30 W S = 1.8 D A = (W − C) S	ELEMENT EFFICIENCY 8	12	15	17	19	20	21	A graduated brightness will be obtained by a single trough located on one side; uniformity if lamps are placed at each side with the ratios as given. See No. 8.
10		D = 0.10 W S = 0.20 W S = D A = WS	ELEMENT EFFICIENCY 13	20	26	31	35	38	40	With highly diffusing translucent materials, the contour of the reflecting background is unimportant. With less diffusing materials, the shape affects the graduation of brightness as does the angle of view. See illustration on page 61 for indication of brightness graduation.
11		S = 0.40 W A = 2 WS	ELEMENT EFFICIENCY 24	35	45	51	—	—	—	Wedge-type elements use a polished aluminum parabolic trough reflector with lamps centered at focus. The slight graduation of brightness (approximately 2 to 1) with cased opal glass sides maintains an effective luminous background for sign letters or decorative patterns.
12		D = 0.36 W S = 0.54 W A = 1.43 WS	ELEMENT EFFICIENCY 33	45	55	65	73	79	83	Lamps should be centered on a line equidistant from both sides; in larger units the shallow cavity may be eliminated.
13		D = 0.50 W S = 0.75 W A = 3 WS	ELEMENT EFFICIENCY 41	55	66	74	80	84	86	Lamps should be centered in the square cross-section. Efficiencies apply to the complete element but the face (F) will be about 25% brighter than the sides when highly diffusing material is used.
14		D = 0.50 W S = 0.70 W A = 4 WS	ELEMENT EFFICIENCY 49	64	76	83	87	90	92	Lamps should be centered in the column whether the cross-section is square, circular, or of other form. Lamps should be positioned as shown to avoid socket shadows and conduit risers should be brought up in one corner or on an inconspicuous side.

Table 13—Computed Average Brightness Values—Foot-Lamberts

$$\text{Foot-Lamberts} = \frac{\text{Element Efficiency } (\%) \times \text{Lamp Lumens} \times \text{Maintenance Factor} \times 144}{100 \times \text{Luminous Area per Lamp (Square Inches)}}$$

(Depreciation from initial values has been allowed in these calculations by the inclusion of a maintenance factor of .70)

Luminous Area per Lamp (Square Inches)	Size of Lamp		ELEMENT EFFICIENCY %						
	Watts	Lumens	20	30	40	50	60	70	80
			FOOT-LAMBERTS						
25	6	38	31	46	61	77	92	107	123
	10	78	63	94	126	157	189	220	252
	15	140	113	169	226	282	339	395	452
	25	258	208	312	416	520	624	728	832
	40	440	355	532	710	887	1064	1242	1419
35	6	38	22	33	44	55	66	77	88
	10	78	45	67	90	112	135	157	180
	15	140	81	121	161	202	242	282	323
	25	258	149	223	297	372	446	520	594
	40	440	253	380	507	634	760	887	1014
	60	762	439	658	878	1097	1317	1536	1756
50	6	38	15	23	31	38	46	54	61
	10	78	31	47	63	79	94	110	126
	15	140	56	85	113	141	169	198	226
	25	258	104	156	208	260	312	364	416
	40	440	177	266	355	444	532	621	710
	60	762	307	461	614	768	922	1075	1229
	75	1065	429	644	859	1074	1288	1503	1718
65	6	38	12	18	24	29	35	41	47
	10	78	24	36	48	60	73	85	97
	15	140	43	65	87	109	130	152	174
	25	258	80	120	160	200	240	280	320
	40	440	136	205	273	341	409	478	546
	60	762	236	355	473	591	709	827	945
	75	1065	330	495	661	826	991	1156	1321
80	6	38	10	14	19	24	29	34	38
	10	78	20	29	39	49	59	69	79
	15	140	35	53	71	88	106	123	141
	25	258	65	98	130	163	195	228	260
	40	440	111	166	222	277	333	388	444
	60	762	192	288	384	480	576	672	768
	75	1065	268	403	537	671	805	939	1074
	100	1530	386	578	771	964	1157	1349	1542
100	10	78	16	24	31	39	47	55	63
	15	140	28	42	56	71	85	99	113
	25	258	52	78	104	130	156	182	208
	40	440	89	133	177	222	266	310	355
	60	762	154	230	307	384	461	538	614
	75	1065	215	322	429	537	644	751	859
	100	1530	308	463	617	771	925	1080	1234
120	10	78	13	20	26	33	39	46	52
	15	140	24	35	47	59	71	82	94
	25	258	43	65	87	108	130	152	173
	40	440	74	111	148	185	222	259	296
	60	762	128	192	256	320	384	448	512
	75	1065	179	268	358	447	537	626	716
	100	1530	257	386	514	643	771	900	1028
140	10	78	11	17	22	28	34	39	45
	15	140	20	30	40	50	60	71	81
	25	258	37	56	74	93	111	130	149
	40	440	63	95	127	158	190	222	253
	60	762	110	165	219	274	329	384	439
	75	1065	153	230	307	383	460	537	613
	100	1530	220	330	441	551	661	771	881
	150	2535	365	548	730	913	1095	1278	1460
160	25	258	33	49	65	81	98	114	130
	40	440	55	83	111	139	166	194	222
	60	762	96	144	192	240	288	336	384
	75	1065	134	201	268	335	403	470	537
	100	1530	193	289	386	482	578	675	771
	150	2535	319	479	639	799	958	1118	1278
180	25	258	29	43	58	72	87	101	116
	40	440	49	74	99	123	148	172	197
	60	762	85	128	171	213	256	299	341
	75	1065	119	179	239	298	358	417	477
	100	1530	171	257	343	428	514	600	685
	150	2535	284	426	568	710	852	994	1136
200	25	258	26	39	52	65	78	91	104
	40	440	44	67	89	111	133	155	177
	60	762	77	115	154	192	230	269	307
	75	1065	107	161	215	268	322	376	429
	100	1530	154	231	308	386	463	540	617
	150	2535	256	383	511	639	767	894	1022
	200	3400	343	514	685	857	1028	1200	1371

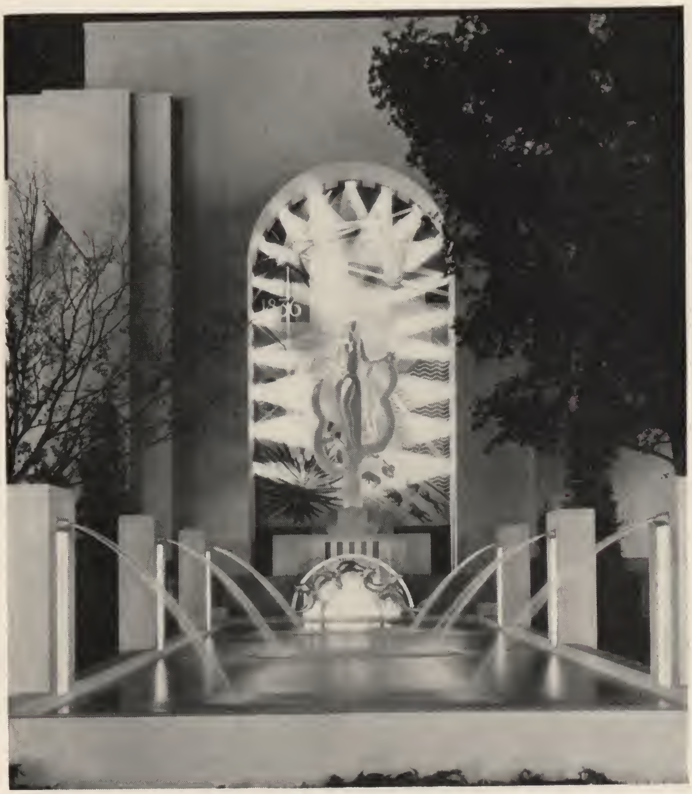
Table 13—Computed Average Brightness Values—Foot-Lamberts

(Depreciation from initial values has been allowed in these calculations by the inclusion of a maintenance factor of .70)

Luminous Area per Lamp (Square Inches)	Size of Lamp		ELEMENT EFFICIENCY %						
	Watts	Lumens	20	30	40	50	60	70	80
			FOOT-LAMBERTS						
250	40	440	35	53	71	89	106	124	142
	60	762	61	92	123	154	184	215	246
	75	1065	86	129	172	215	258	301	344
	100	1530	123	185	247	308	370	432	494
	150	2535	204	307	409	511	613	715	818
	200	3400	274	411	548	685	823	960	1097
300	40	440	30	44	59	74	89	103	118
	60	762	51	77	102	128	154	179	205
	75	1065	72	107	143	179	215	250	286
	100	1530	103	154	206	257	308	360	411
	150	2535	170	256	341	426	511	596	681
	200	3400	228	343	457	571	685	800	914
350	40	440	25	38	51	63	76	89	101
	60	762	44	66	88	110	132	154	176
	75	1065	61	92	123	153	184	215	245
	100	1530	88	132	176	220	264	308	353
	150	2535	146	219	292	365	438	511	584
	200	3400	196	294	392	490	588	685	783
	300	5520	318	477	636	795	954	1113	1272
400	40	440	22	33	44	55	67	78	89
	60	762	38	58	77	96	115	134	154
	75	1065	54	81	107	134	161	188	215
	100	1530	77	116	154	193	231	270	308
	150	2535	128	192	256	319	383	447	511
	200	3400	171	257	343	428	514	600	685
	300	5520	278	417	556	696	835	974	1113
500	60	762	31	46	61	77	92	108	123
	75	1065	43	64	86	107	129	150	172
	100	1530	62	93	123	154	185	216	247
	150	2535	102	153	204	256	307	358	409
	200	3400	137	206	274	343	411	480	548
	300	5520	223	334	445	556	668	779	890
	500	9800	395	593	790	988	1185	1383	1581
700	60	762	22	33	44	55	66	77	88
	75	1065	31	46	61	77	92	107	123
	100	1530	44	66	88	110	132	154	176
	150	2535	73	110	146	183	219	256	292
	200	3400	98	147	196	245	294	343	392
	300	5520	159	238	318	397	477	556	636
	500	9800	282	423	564	706	847	988	1129
900	60	762	17	26	34	43	51	60	68
	75	1065	24	36	48	60	72	83	95
	100	1530	34	51	69	86	103	120	137
	150	2535	57	85	114	142	170	199	227
	200	3400	76	114	152	190	228	267	305
	300	5520	124	185	247	309	371	433	495
	500	9800	220	329	439	549	659	768	878
	750	14550	326	489	652	815	978	1141	1304
1300	75	1065	17	25	33	41	50	58	66
	100	1530	24	36	47	59	71	83	95
	150	2535	39	59	79	98	118	138	157
	200	3400	53	79	105	132	158	185	211
	300	5520	86	128	171	214	257	300	342
	500	9800	152	228	304	380	456	532	608
	750	14550	226	338	451	564	677	790	903
	1000	20700	321	482	642	803	963	1124	1284
1500	100	1530	21	31	41	51	62	72	82
	150	2535	34	51	68	85	102	119	136
	200	3400	46	69	91	114	137	160	183
	300	5520	74	111	148	185	223	260	297
	500	9800	132	198	263	329	395	461	527
	750	14550	196	293	391	489	587	684	782
	1000	20700	278	417	556	696	835	974	1113
1700	150	2535	30	45	60	75	90	105	120
	200	3400	40	60	81	101	121	141	161
	300	5520	65	98	131	164	196	229	262
	500	9800	116	174	232	291	349	407	465
	750	14550	173	259	345	431	518	604	690
	1000	20700	245	368	491	614	736	859	982
1900	150	2535	27	40	54	67	81	94	108
	200	3400	36	54	72	90	108	126	144
	300	5520	59	88	117	146	176	205	234
	500	9800	104	156	208	260	312	364	416
	750	14550	154	232	309	386	463	540	618
	1000	20700	220	329	439	549	659	769	879
2200	200	3400	31	47	62	78	93	109	125
	300	5520	51	76	101	126	152	177	202
	500	9800	90	135	180	225	269	314	359
	750	14550	133	200	267	333	400	467	533
	1000	20700	190	285	379	474	569	664	759
2500	200	3400	27	41	55	69	82	96	110
	300	5520	45	67	89	111	134	156	178
	500	9800	79	119	158	198	237	277	316
	750	14550	117	176	235	293	352	411	469
	1000	20700	167	250	334	417	501	584	668

SPECIALIZED APPLICATIONS

New products, structural materials, and modern design principles have introduced a great variety of forms in which light has both utilitarian and decorative value. Store fronts and signs, in particular, have yielded to the magic of modern lighting treatment, and Exposition lighting, in the past few years, has given occasion for the design and application of many extraordinary and ingenious displays. The following illustrate successful luminous treatments in specialized applications.



A striking example of lighting and architectural composition from the Texas Centennial Central Exposition. Luminous vertical glass brick panels cast reflections in the pool and illuminate flat jets of water. Concealed floodlight projectors crisscross a pattern of brilliance and color on the 50-foot background which symbolically portrays Texas and provides a background for the statue, Inspiration of the Centennial.

An avenue of colorful luminous elements from Cleveland's Great Lakes Exposition. A silhouette trough conceals tubular and natural colored lamps arranged in pairs to cast alternate narrow and wide double bands of light reflections in the polished corrugated metal background.

Glass Brick

One of the most versatile of the new structural materials is glass brick which offers an excellent opportunity for the effective use of light for decorative effects. Available with fluting, prismatic patterns, or configurated surfaces, interesting and sparkling highlights are introduced when these glass bricks are transilluminated. Banded or plaid effects produced by colored Lumiline lamps behind this structural glass offer an effective treatment for decorative display.

Block Letters—Wedge Signs

Large block letter signs constructed of luminous glass panels are attention-compelling by day because of their size and conformation, and assert themselves at night because of their dominant brightness.

The luminous wedge, evolved from the demand for a modern architectural element, is an inexpensive, well-engineered luminous sign. The lamps in a parabolic trough reflector located in the base of the wedge produce substantially uniform brightness over the faces of the sign when such faces are placed at 17° to 22° angle to each other. The luminous wedge sign is light and neat in appearance, with finish and lines conforming to modern design.

Silhouette Letters

Letters or decorative patterns in silhouette against a brightly lighted white or tinted background proclaim the advertiser to be in step with modern methods. Pleasing uniformity of background brightness is important to the success of this type of display. The lamps, concealed from view in channels behind the letter strokes, should be spaced not more than 1½ times their distance out from the background.

Multiplane Silhouette Letters

Multiplane silhouette displays—a further development of the single silhouette display—have the added advantage of depth and over layers of color not possessed by the single silhouette. Use of natural colored lamps and a definite cycle of color change produces an attractive and continually changing appearance.

Edge Lighting

Edge lighting of signs and decorative elements use the property of clear glass to conduct and confine the light rays within the glass until they are scattered by some sort of obstruction such as etched letters upon the glass which produces a luminous effect. Widespread use of this characteristic is found particularly in small signs for interiors. Another attractive use of edge lighting are glass panels engraved and sandblasted in attractive designs and placed in niches with a dark background. Color may be used effectively in most edge-lighted applications.

ILLUMINATION TERMS

ABSORPTION: The loss occurring when light traverses a designated medium or reflects from a designated surface. The ratio of the absorption to the incident light is called *Absorption Factor*. For any surface or medium, *Absorption* plus *Transmission* plus *Reflection* = Incident Light. For any surface or medium *Absorption Factor* plus *Reflection Factor* plus *Transmission Factor* = 1.00

BRIGHTNESS: The degree of brilliancy of any part of a surface or medium, when viewed from a designated direction. It is measured by the ratio of the candlepower emitted in that direction, to the area as projected in that direction (i.e. the apparent area as seen from that direction). It may also be expressed in lumens per unit of area of a perfectly diffusing surface of equal brightness Since most surfaces or mediums are not perfectly diffusing, the brightness varies with the point of view. In all ordinary cases brightness is independent of the distance of observation.

The common units of brightness and their relation is as follows:

1 *Candle per Square Inch* = 452 foot-lamberts
= .487 lamberts
= 487 millilamberts.

1 *Foot-Lambert* = 1 lumen per square foot reflected or emitted
= .00221 candles per square inch
= 1.076 millilamberts.

1 *Lambert* = 1 lumen per square centimeter reflected or emitted
= 1000 millilamberts
= 929 foot-lamberts
= 2.054 candles per square inch.

1 *Millilambert* = .929 foot-lamberts
= .002054 candles per square inch.

The candle per square inch and lambert are commonly used for high brightness such as of light sources.

The foot-lambert and millilambert for ordinary illuminated surfaces.

The foot-lambert = incident footcandles × reflection factor, assuming a diffusing surface or medium.

Brightness is assuming more and more importance in planning for ability and comfort of seeing. Either extremely high brightness, or excessive contrast of brightness—high *Brightness Ratio*—is liable to cause glare. Very low brightness lessens ability to see.

CANDLE: The unit of luminous intensity in a designated direction from a point light source—i.e. one having small dimensions compared with the distance at which it is measured. The *International Candle* is the unit agreed upon by United States, Great Britain and France in 1909, it is .98 of the British Candle used in the United States before 1909.

COLOR OF LIGHT: *Average daylight* (Color Temperature approximately 6000°) is scientifically taken as the standard of white light, though daylight itself is subject to a variation due to position of the sun, state of cloudiness, reflection from buildings, foliage and, indoors, room finishes. *North skylight* is more blue than average daylight, and has been used as a standard in dyeing and other color work because less subject to variation, although average daylight would be more representative of conditions of use. *Direct sunlight* is always yellow tinted and when the sun is near the horizon decidedly yellow tinted. *Incandescent light* is yellow tinted, the more efficient lamps producing the closer approximation to daylight.

DIFFUSION: A scattering of light rays, so as to cross each other, as opposed to regular radiation of light from a point source. Diffusion may be introduced by reflection from a matte surface or transmission through a frosted or opal glass. This tends to enlarge the image of the light source (e.g. lamp filament) reducing its brightness and breaking up its outline.

DISTRIBUTION OF ILLUMINATION: The manner in which the footcandles of illumination vary over a specified area (e.g., the horizontal working plane—30 inches or 36 inches above the floor). Even distribution occurs when there is relatively little variation. Spotty distribution refers to extreme variation. In an artistic interior a certain amount of variation is usually desirable.

DISTRIBUTION OF LIGHT: For a light source or complete luminaire, refers to the candlepower emitted in various directions. For most illuminants, the candlepower is substantially equal in all directions about the vertical axis. For such Symmetrical Distributions it is customary to plot polar curves of which the radius representing any angle of elevation is proportional to the candles toward that elevation.

EFFICIENCY: For electric lamps or luminaires, the lumen output per watt of power supplied. For lamps requiring power consuming regulators or ballasts, a distinction should be made between the efficiency of the lamp proper and the lower *over-all efficiency* of the practical lighting equipment. For reflectors, globes and other accessories used with an incandescent lamp or other lamp, the efficiency is the ratio of the lumens delivered by the accessory to the total light of the lamp, expressed as a percentage.

FLUX OF LIGHT: Light actually represents a flow of energy and its volume is treated scientifically as a time rate or flux. In practice, however, the rate of flow in artificial lighting is usually considered constant and treated as a static condition. Flux is measured in lumens. (See Lumens.)

FOOTCANDLE: The unit of illumination and the measure of density of the light falling on any surface. It is equal to one lumen per square foot of area. When light from a point source falls perpendicularly on a plane—the illumination in footcandles on the plane is equal to the candles, emitted by the source in that direction, divided by the square of the distance in feet. Footcandles at any point on a plane can be measured by the Light Meter.

The LUX is the unit of illumination commonly used in countries employing the metric system. 1 F.C. = 10.76 Lux. (See also Lumen.)

GLARE: A condition of lighting in which part of the light interferes with seeing, causes eyestrain or discomfort.

Common causes of glare are (1) viewing a brilliant light source, directly or by reflection, (2) high contrast of brightness, especially when trying to see in the field of lower brightness, (3) an excessive volume of light reaching the eyes.

LOUVER: A shield used in connection with a lamp or luminaire to intercept light traveling in undesirable directions, used for glare prevention, for accurate control or for other reasons.

LUMEN: The unit of luminous flux, equal to the light through a unit solid angle (Steradian) from a uniform point source of one candle. The application of the lumen is universal. It can express the total output of any light source, the output of a point source in any solid angle, the light received upon any area, light absorbed, reflected or transmitted.

Lumens = candles × Steradians = footcandles × square feet. The total output of a lamp = spherical candles × 12.57. (The total solid angle about a point is 4 × 3.1416 or 12.57 Steradians.)

LUMINAIRE: A complete lighting equipment consisting of a light source together with its direct appurtenances such as globe, reflector, refractor, housing and such support as is integral with the housing. Designates completely equipped lighting fixtures, chandeliers, wall brackets, portable lamps and other units of which the prime function is the production of illumination.

PARABOLIC REFLECTOR: A reflector or mirror which has its reflecting surface in the form of a paraboloid. Possesses the property of reflecting the light from theoretical point source located at the focus with all rays parallel to the axis. In practice, high concentration can be obtained but the divergence of the beam will be proportional to the angle subtended by the source in relation to the focal length of the reflector used. The spread is increased by moving the source away from the focal point.

REFLECTION FACTOR: The ratio of the light reflected by a designated surface or body, to the incident light. For surfaces having both diffuse and regular reflection it is the sum of the *Diffuse Reflection Factor* and *Regular Reflection Factor*. (See Absorption.)

TRANSMISSION FACTOR: The ratio of the light transmitted by a transparent or translucent medium (e.g. opal glass) to the light incident upon it.

Transmission may be regular or diffuse. The *Regular Transmission Factor* plus *Diffuse Transmission Factor* = Transmission Factor. (See Absorption.)

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REFLECTION FACTORS
•
OF VARIOUS COLORED PAINTS
•
AND NATURAL WOOD FINISHES
•

The effect of the color of walls and ceilings on illumination efficiency is one of the important considerations in the design of a lighting installation. The influence of interior finish is least important with opaque direct lighting reflectors, more pronounced with translucent semi-direct units and becomes a major consideration with semi-indirect and indirect systems. A complete specification for lighting should, therefore, include suggestions as to painting and interior finish.

This folder includes a wide range of color samples so that the reflection factor of any colored surface can be approximated by comparison with the colors shown. The percentage below each color is the proportion of the light of Mazda lamps which these surfaces reflected and will vary somewhat for light sources of other spectral quality. Where acoustical material is used for the ceiling, reflection factors are lower, yet it is possible to obtain many acoustical materials either in their natural finish, or when properly painted, with reflection factors ranging from 60% to 75%.

There is much to be gained by an understanding of the psychology of color. For example, a room finished in warm tones, such as cream or buff, not only makes it seem warmer but also has the effect of making a room seem smaller. On the other hand, cool colors, such as light green or blue, seem to recede, making a room appear larger and cooler. This latter fact is quite important, particularly where high levels of illumination are installed, since cooler colors counteract the feeling that a brightly lighted room is uncomfortably warm in summer, even though the actual temperature rise can scarcely be measured.

In general mat or eggshell finish is to be preferred to gloss for ceilings and other reflecting surfaces, since it diffuses the light and does not mirror the high brightness of the light source. The former finish is equal to or superior to gloss finish in reflection factor.

The paper has been scored vertically to facilitate folding so that any row of color samples may be placed adjacent to other surfaces for comparison.


85%
77%
72%
66%
75%
70%
66%
57%
66%
65%
61%
48%
59%
60%
55%
40%
49%
52%
50%
34%
40%
41%
44%
27%
30%
30%
35%
21%
CURLY MAPLE
52%
PRIMA VERA
50%
SATIN WOOD
34%
QT. OAK
33%


76%
61%
77%
67%
75%
57%
77%
40%
74%
51%
76%
48%
70%
46%
69%
14%
65%
42%
67%
9%
58%
40%
63%
7%
53%
34%
60%
7%
LACEWOOD
27%
ENG. OAK
17%
WALNUT
16%
ORIENTALWOOD
14%